Alaska Habitat Management Guide

Impacts of Land and Water Use on Fish and Their Habitat

Part II

Produced by
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Division of Habitat

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Contents

Introduction to Part 2

This is part 2 of a two-part volume containing documented impacts resulting from various types of land and water development on marine fish and shellfish, freshwater fish, and their habitats. Part 1 of this volume is separately bound and contains the topical index to and supplemental materials for the annotated bibliography presented here. There are two indices in part 1, one organized by type of developmental activity (e.g., blasting, channelizing waterways, etc.) and the other by type of impact (e.g., change in turbidity of suspended sediments, change in temperature of water, etc.). Lists of activities and impacts are provided in part 1, appendices C and D, respectively. For more information on how to use parts 1 and 2 most efficiently, see the users' guide in the introduction to part 1.

The format of this section displays one annotation per page. This has been done in order to make it easy to update this volume with additional annotations.

All annotations presented in this document are arranged in alphabetical order according to author. However, users should note that authors' names containing internal capital letters and/or blank space are treated as special characters by the automated sorting algorithm. All capital letters are ordered before lowercase letters (e.g., DeGange before Decker), and blank spaces preceed all capital and lowercase letters (e.g., R and M Consultants before Rabens).

Each annotation consists of three parts: 1) full bibliographic information, 2) a narrative section, and 3) specific activity and impacts to which the reference has been coded in the indices in part 1 of this volume. Full bibliographic information is provided for users who wish to acquire the source documents for particular annotations. To facilitate this, each reference reported in this document has been placed in the Alaska Department of Fish and Game, Habitat Library, in Anchorage, Alaska. Additionally, the citation number for each book or reprint has been included at the end of the bibliographic information field (B__ or R__, respectively). Use of these citation numbers when searching for or requesting to borrow materials will greatly reduce the time required to locate documents. Users are urged to avail themselves of this time-saving feature.

In preparing the narrative sections of the annotations, a high priority was placed on maintaining a true representation of the intent of the author. Therefore, whenever possible we made use of abstracts, summaries, and/or conclusions prepared by the original authors. The portions of original text used to prepare annotations is indicated at the end of the narrative section.

The activities and impacts to which each annotation is coded are provided as a means of improving the quality of the database over time. It is anticipated that as people use this document, they will encounter occasional errors in the coding. If this occurs, we urge you to take a moment to notify us in order that updated versions of this document will improve in quality. To minimize the effort on your part, error correction forms are provided in appendix E, part 1 of this volume.

In preparing the annotations, we reported the data in each study in the same units as used by the author. Thus, both metric and English units are used. Whenever possible, abbreviations were also used to designate agencies, locations, and other selected terms. Abbreviations used in the narratives are as follows:

Units of Measure

Length	
kilometer	km
meter	m
centimeter	cm
millimeter	mm
micrometer	um
nanometer	nm
mile	mi
yard	yd
foot	ft
inch	in
Weight	
kilogram	kg
gram	g
milligram	mg
microgram	ug
nanogram	ng
pound	lb
ounce	oz
Volume/area	
hectare	ha
liter	l
milliliters	ml
microliter	ul
nanoliter	nl
square units	$unit^2$
cubic units	$unit^3$
Time	
year	yr
month	mo

week	wk
day	d
hour	h or hr
minute	min
second	s

Other units

degrees Celsius	°C
degrees Fahrenheit	°F
percent	%
parts per thousand	ppt or 0/00
parts per million	ppm
parts per billion	ppb
hertz	Hz

Agencies, Organizations, and Other Terms

ACMP	Alaska Coastal Management Program
ADCED	Alaska Department of Commerce and Economic Development
ADCRA	Alaska Department of Community and Regional Affairs
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADL	Alaska Department of Labor
ADNR	Alaska Department of Natural Resources
ADR	Alaska Department of Revenue
AEIDC	Arctic Environmental Information and Data Center
ATPase	Adenosine triphosphatase
BLM	Bureau of Land Management
BOD	Biological oxygen demand
CPUE	Catch per unit effort
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved oxygen
ED_{50}	Effective dose, 50%
EPA	Environmental Protection Agency
EPS	Environmental Protection Service (Canada)
ERL	Environmental Research Laboratory
FAO	Food and Agriculture Organization of the United Nations
FTU	Formazin turbidity unit
ID_{50}	Infective dose, 50%
IMS	Institute of Marine Science
INPFC	International North Pacific Fisheries Commission
IPHC	International Pacific Halibut Commission
LC_{50}	Lethal concentration, 50%
LD_{50}	Lethal dose, 50%
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council
NPS	National Park Service

NWAFC	Northwest and Alaska Fisheries Center
NWR	National Wildlife Refuge
PCB	Polychlorinated biphenols
PWS	Prince William Sound
TLM	Median tolerance limit
TU	Temperature units
USACRREL	U.S. Army Cold Regions Research and Engineering
USDA	United States Department of Agriculture
USDC	United States Department of Commerce
USDI	United States Department of Interior
USDL	United States Department of Labor
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
V/V	Volume per volume ratio
WSF	Water-soluble fraction

Annotated Bibliography

ADEC and R and M Consultants. 1980. Manual of recommended practices for transportation corridor development roads, railroads, pipelines, subdivisions. Final report. ADEC, Alaska Water Qual. Manage. Planning Prog., Non-point Source Study Series Section 208, PL 92-500,95-217. (ADF&G, Habitat Library, #B2181.)

This is a manual of recommendations for controlling erosion and sedimentation in development of transportation facilities, roads, railroads, pipelines, and subdivisions. Recommendations apply to design, construction, and maintenance.

Construction activities are classified by the headings, Group and Practice. Each Practice is described under a series of subsequent headings. Many of the Practices (construction activities) serve some primary purpose other than erosion and sediment control; but discussions under the subheadings (Purpose, Site Characteristics, Description) refer only to those applications that in some way control erosion and sediment. Helpful figures and diagrams are included.

The selection of alternative design features, such as bridges or culverts for stream crossings, is not directly addressed here. Those decisions should be made on the basis of sound engineering judgement applied to specific sites and situations. This manual does, however, provide information and suggestions on how to protect water quality in the design, installation, and maintenance of such structures. Trade-offs will occur between such things as initial cost, maintenance required, project life, and right of way required. Freqently, several other professional disciplines should also be included in decision making.

The following eight topics are included: 1) earthwork, 2) drainage (i.e., culverts, low-water crossings and inlet/outlet protection), 3) decurrent retention - ponds and buffer strips, filter and traps, etc., 4) slope stabilization, 5) revegetation and mulching, 6) streambank stabilization, 7) thermal erosion control, and 8) icing control on drainage structures and in channels.

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

ADF&G. 1983. Fishery productivity and in stream mining: a resource conflict in the Bristol Bay region. [Anchorage, AK.] 37 pp. + 46 pp. Annotated bibliography. (ADF&G, Habitat Library, #B6251.)

Information from 114 citations of published and unpublished literature is synthesized into 38 pages of text. Approximately one-half of the text focuses on the effects of turbidity and sedimentation of all life stages of anadromous salmonids and on stream productivity. The remainder of the narrative includes a summary of existing legislation regarding anadromous streams and an evaluation of the effects of instream mining on commercial, sport, and subsistence fisheries. Significant conclusions include the following:

1) Sedimentation is detrimental to incubating embryos because it reduces the rate at which water moves through the gravel. This reduces the rate of replenishment of dissolved oxygen to embryos and reduces the removal of waste metabolites.

2) Available data show that dissolved oxygen concentrations greater than 8 mg/l may be necessary to ensure normal development and high survival rates for salmonid embryos; the current State of Alaska legal standard for streams supporting fish life is 7 mg/l.

3) Nonlethal effects of low dissolved oxygen levels include smaller sized alevins at hatching, delayed hatching, and an increase in the incidence of deformities. Depositions of sediment also reduces available rearing habitat for juveniles, which results in increased intraspecific aggression. Juveniles without feeding areas may be displaced or die from starvation.

Activity: dredging; processing minerals.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Adams, J.N., and R.L. Beschta. 1980. Gravel bed composition in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 37: 1514-1521. (ADF&G, Habitat Library, #R2303.)

The amount of fine sediments (generally less than 1 mm in diameter) in gravel-bedded streams is often used as an indicator of habitat quality and also as a measure of the impact from accelerated sedimentation resulting from land disturbance. Five streams in the Oregon Coast Range were studied to evaluate temporal and spatial variability of streambed composition, as well as the factors affecting the amount of fine sediment within the bed. The amount of fine sediments (less than 1 mm) contained in frozen streambed cores and expressed as a percentage (by weight) of the total sample proved highly variable in time and space. During a 19-mo sampling period, temporal variability was caused by an occasional flushing of fines from the gravel beds during high flows. Percent fines also varied greatly between streams, between locations in the same stream, and between locations in the same riffle. Streams on 21 Coast Range watersheds were sampled during summer low flow. The amount of fines averaged 19.4% for all watersheds and ranged from 10.6 to 29.4% for streams on undisturbed watersheds. Regression analysis indicated that the watershed slope, area, relief, and land use influenced the amount of fine sediment in the bed. Bed composition varied greatly between locations in the same stream with about 75% of the within-stream comparisons indicating a significant (alpha = 0.05) dfference. Within a single stream, gravel bed composition correlated significantly with channel sinuosity and bank-full stage. Regression analysis and field observations suggested that road construction and logging operations can increase the amount of fines; however, such increases may be temporary if high flows flush the gravels. (Authors abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments.

Aldrich, J.W., and R.A. Johnson. 1979. Surface erosion and sedimentation associated with forest land use in interior Alaska. Institute of Water Resources, Univ. Alaska, Fairbanks. Rept. No.IWR-99. 87 pp. (ADF&G, Habitat Library, #R2909.)

This report discusses the magnitude of sheet-rill erosion associated with various landscape manipulations and confirms the usefulness of the Universal Soil Loss Equation for predicting annual sheet-rill erosion within interior Alaska. The field investigations of sheet-rill erosion in 1978 indicated that clearing the trees from forested areas with only minor ground cover disturbance did not increase erosion. However, removing the ground cover increased erosion 18 times above that on forested areas. Erosion was substantially reduced by 95% when disturbed areas were covered with straw mulch and fertilizer. Comparison of the actual erosion and the quality of erosion predicted with the Universal Soil Loss Equation indicated that the equation overestimated individual storm erosion by an average of 174%. Data are also presented on sheet-rill erosion in a permafrost trail, distribution of the rainfall erosion index, and suggested cover and management factor values.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Alexander, G.R., and E.A. Hansen. 1977. The effects of sediment from a gas-oil well drilling accident on trout in creeks of the Williamsburg area, Michigan. Mich. Dept. Nat. Res., Fish. Div. Fish. Res. Rept. No. 1851. 15 pp. (ADF&G, Habitat Library, #B3690.)

A gas-oil well-drilling accident caused abnormally large quantities of sediment-laden water to enter trout streams of the Williamsburg area, Michigan. Uncontrolled natural gas moved up the well shaft from approximately 5,000 ft and moved laterally through a limestone formation at about 1,500 ft. As the gas moved upward, it carried groundwater with it and created small geysers where it erupted at the surface. The muddy water discharged from the geysers then flowed into nearby streams. This study was undertaken to assess the impacts on salmonids.

Suspended sediments reached 4,600 ppm two days following the accident (April 18, 1973). A steady reduction in concentration during the first two weeks was followed by stabilization at generally less than 100 ppm. Concentrations in control streams were less than 15 ppm during the same period.

No abnormal concentrations of dissolved solids or dissolved oxygen were noted, and stream water temperatures were not elevated. Sediment concentrations were greatly increased, and some sediment deposition occurred on the streambed.

For analysis, all species of salmonids were pooled. The most numerous salmonids were brown trout, a species not found in Alaska. However, remaining species, in order of abundance were rainbow trout, brook trout, coho salmon, and chinook salmon. Fish were captured by electrofishing, and population estimates were derived using the Petersen mark-and-recapture method. Representative groups of salmonids were scale-sampled for age and growth analysis.

No quantitative fisheries population information was available for the streams prior to the accident. Population estimates derived over several years after the eruption were compared for changes in trends between exposed and unexposed areas. Analysis demonstrated that salmonid populations in the affected streams were reduced for a number of years and had nearly recovered in 1976 as suspended sediment concentrations dropped to 40-60 ppm.

No significant change in individual growth rate was noted; however, the growth of biomass was depressed in affected streams.

Activity: drilling.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

Allen, K.O., and J.W. Hardy. 1980. Impacts of navigational dredging on fish and wildlife: a literature review. USFWS, Biological Services Program. FWS/OBS/-80/07. 81 pp. (ADF&G, Habitat Library, #B6121.)

This document provides a discussion of dredging impacts and habitat enhancement opportunities. The authors address impacts of navigational dredging and habitat development for coastal waters and rivers. They also include descrip- tions of types of dredging equipment, characteristics of dredged material, evaluation of the pollution potential of various methods, and habitat development options and enhancement opportunities resulting from dredged material disposal. This review includes impacts to fish, other aquatic organisms, and wildlife resulting from construction of new navigational channels and maintenance dredging of existing channels. Both dredging and disposal stages are discussed. This review does not cover other types of dredging, such as canal construction for oil and gas exploration and extraction, dredging for residential or commercial development, sand and gravel dredging, shell dredging, or channelization of streams for flood control.

Activity: dredging; filling (terrestrial); solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Anderson, H.W. 1971. Relative contributions of sediment from source areas, and transport processes. Pages 55-63 in J.T. Krygier and J.D. Hall, eds. Proceedings of a symposium on forest land uses and stream environment, October 19-21, 1970. Oregon State Univ., Corvallis, OR. (ADF&G, Habitat Library, #R5088.)

This paper reports new findings, offers a reanalysis of older studies, and summarizes pertinent results in the literature. Past land use, forest fires, road building, "poor logging", and conversion of steep lands to grass have increased sediment discharge by factors ranging from 1.24 to more than 4. Projected future use is expected to increase sediment production by a factor of 4, with 80% associated with roads and 20% with logging. Major floods have increased subsequent turbidity of streamflow by a factor of 2. The increases were greater in logged areas of watersheds where roads were next to streams and landings were in draws than in undisturbed watersheds. Most landslides were associated with road development, next most with logged areas, and least with undisturbed forest area. The number of turbid days in streamflow varied by a factor of 2.34 with differences in silt plus clay content of soils, by 8.55 with differences in erodibility, and by 4.3 with the percentage of gravel. Further, these soil characteristics were predictable from geologic rock types. In a sample calculation, 89% of channel bedload became suspended load enroute downstream. Soil creep contributed 15% to total sediment discharge from watersheds; channel bank erosion contributed 54 to 55% (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials.

Anderson, J.B., and B. Broekstra. 1977. Thermal wedging in Lake Macatawa, Michigan: long-term impact of channelization. J. Great Lakes Res. 3(1-2):159-163. (ADF&G, Habitat Library, #R5090.)

Bottom-wedging of cold Lake Michigan waters into Lake Macatawa, Michigan, through a connecting ship channel occurs frequently during summer months and results from upwelling in Lake Michigan. This thermal wedging causes sporadic flushing of sediment-laden waters into Lake Michigan, pronounced artificial stratification in Lake Macatawa, which may lead to anoxic bottom conditions, and pronounced drops in bottom termperature.

Because Lake Macatawa, like many other coastal lakes and rivers located along the Great Lakes, has been connected to Lake Michigan via an artificial ship channel, the process of thermal wedging is an unnatural one. Influences of thermal wedging upon the lake environment should be considered in evaluating the long-term effect of channel construction.

Activity: channelizing waterways.

Impact: change in water temperature; change in level of dissolved oxygen, nitrogen.

Anderson, L., and M. Bryant. 1980. Fish passage at road crossing: an annotated bibliography. USDA: Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. Gen. Tech. Rept. No. PNW-117. 10 pp. (ADF&G, Habitat Library, #R3824.)

This bibliography lists 45 publications pertinent to road crossings of salmon and trout streams; however, there is no synethesis of information presented. Included are data on swimming speeds, water velocity and rates of passage, light requirements, hydraulic evaluation, design criteria, evaluation of installations, culvert installations, economics, bridge installation and special applications (e.g., arch culverts, baffles, fishways, slot orifices, and other adaptations).

Activity: stream crossing - structures.

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Anderson, E.P., I.K. Birtwell, S.C. Byers, A.V. Hincks, and G.W. O'Connell. 1981a. Environmental effects of harbour construction activities at Steveston, British Columbia. Part 1: Main report. Can. Tech. Rept. Fish. Aquat. Sci. 1070: vii + 153 pp. (ADF&G, Habitat Library, #B1069.)

From January to December 1979, the authors sampled the estuarine biota and environment at Steveston Harbour, near the mouth of the Fraser River, in order to assess the effects of harbour development. They found no unacceptable levels of heavy metal or organic pollutants. During periods of intensive fish processing, harbour waters showed elevated concentrations of ammonia and phosphate. Dissolved oxygen was somewhat depressed in the near-bottom water at the landward end of the harbour.

The subtidal benthos was divisible into three community types, corresponding to deep silt, shallow silt, and sand habitats. The deep silt community repopulated a small dredged area within 1 mo after dredging stopped.

Juvenile chum salmon (Oncorhynchus keta) and/or chinook salmon (Oncorhynchus tshawytscha) were captured by beach seine from February through October, with largest numbers in March, April, and May. Juvenile chum salmon were clearly more abundant near the marsh habitat than near sand. The most common items in salmon stomachs were harpacticoid copepods, chironomid insects, and oligochaete worms. The species composition of stomach contents did not closely correspond to that of benthic samples, but there was some evidence that juvenile salmon fed more successfully near marsh than near sand shores. One common effect of harbour dredging is to replace marsh with sand. (Authors' abstract)

Activity: dredging; filling (aquatic and wetland habitats); solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of nutrients.

Anderson, E.P., I.K. Birtwell, S.C. Byers, A.V. Hincks, and G.W. O'Connell. 1981b. Environmental effects of harbour construction activities at Steveston, British Columbia. Part 2. Appendices. Can. Tech. Rept. Fish. Aquat. Sci. 1071: vii + 153 pp. (ADF&G, Habitat Library, #B1069.)

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Anderson, E.P., I.K. Birtwell, S.C. Byers, A.V. Hincks, and G.W. O'Connell. 1981c. Environmental effects of harbour construction activities at Steveston, British Columbia. Part 3. Interpretive summary. Can. Rep. Fish. Aquat. Sci., No. 1072. v + 41 pp. (ADF&G, Habitat Library, #B1069.)

From January to December 1979, the authors sampled the estuarine biota and environment at Steveston Harbour, near the mouth of the Fraser River, in order to assess the effects of harbour development. They found no unaceptable levels of heavy metal or organic pollutants. During periods of intensive fish processing, harbour waters showed elevated concentrations of ammonia and phosphate. Dissolved oxygen was somewhat depressed in the near-bottom water at the landward end of the harbour.

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Activity: dredging; filling (aquatic and wetland habitats); solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of nutrients.

Antoine, S.E., and K. Benson-Evans. 1982. The effect of current velocity on the rate of growth of benthic algal communities. Int. Revue ges. Hydrobiol. 67:575-583. (ADF&G, Habitat Library, #R5146.)

The effect of three different current velocities on the growht of benthic algal communities colonizing blocks of natural rocks was studied using laboratory channels. Standing crop of most species of the Chlorophyta and of the single myxophytan species present together with chlorophyll-a values for the total population all showed an inverse relationship with the current velocities. Chasmarium reniforme disappeared in all three current velocities. Various species of the Bacillariophyta reacted differently to current velocity, and 10 patterns of response were observed.

Activity: channelizing waterways; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water.

Arner, D.H., H.R. Robinette, J.E. Frasier, and M.H. Gray. 1976. Effects of channelization of the Luxapalila River on fish, aquatic invertebrates, water quality, and furbearers. FWS/OBS-76/08. USFWS, Washington, D.C. 66 pp. (ADF&G, Habitat Library, #B1741.)

Biological data collected from July 1973 to January 1976 from an old channelized segment (over 52 yr), an unchannelized segment, and a newly channelized segment of the Luxapalila River, Mississippi and Alabana, revealed that productivity of the old channelized segment has not recovered to the levels exhibited in the unchannelized segment. There were no evident differences in water quality between the three segments except for higher turbidity trends in the newly channelized segment. The number of plankton organisms was higher in the newly channelized segment, possibly due to the influence of sewage. Diversity of plankton, macroinvertebrates, and fish was significantly higher ($P<.05$) in the unchannelized segment. Average weight of largemouth bass was greater in the unchannelized than in either of the channelized segments. The length frequency histogram of this species shows a more normal distribution of length classes in the unchannelized segment, whereas in the two channelized segments there is an evident skewed array toward the smaller-length classes. Utilization of an expanding habitat created by annual flooding was indicated by the preponderance of terrestrial invertebrates found in stomachs of fish collected behind the levee. Indices of abundance of furbearers associated with the river were obtained by night lighting, sign count, and trapping. Muskrat and beaver, the species most commonly associated with an aquatic habitat, were far more numerous in the unchannelized segments. (Author's abstract)

Activity: channelizing waterways.

Impact: change in turbidity or suspended sediments; introduction or removal of species.

Atlas, R.M., A. Horowitz, and M. Busdosh. 1978. Prudhoe crude oil in arctic marine ice, water, and sediment ecosystems: degradation and interactions with microbial and benthic communities. J. Fish. Res. Bd. Can. 35: 585-590. (ADF&G, Habitat Library, #R1004.)

A variety of *in situ* models were used to simulate oil spills in different arctic ecosystems. The numbers of oil-degrading microorganisms were found to increase after oil contamination. Oil contamination of sediment resulted in mortality of indigenous invertebrates. Recolonization of sediments began shortly after contamination, but benthic communities were significantly different in contaminated sediment compared with the control two months after oil contamination. Petroleum hydrocarbons were degraded slowly. Ice greatly restricted losses of light hydrocarbons. Following initial abiotic losses, biodegradation of oil was limited and did not significantly alter the relative percentages of hydrocarbons in the residual oil. The authors conclude that petroleum hydrocarbons will remain in arctic ecosystems for prolonged periods after oil contamination. (Author's abstract: modified)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Aukerman, R., and W.T. Springer. 1976. Effects of recreation on water quality in wildlands. Dept. of Recreation Resources, Colorado State Univ. USDA Eisenhower Consortium Bull. 2. 25 pp. (ADF&G, Habitat Library, #B0975.)

This field study was designed to isolate and evaluate the water quality impact of recreational campground use in a watershed in northern Colorado. The findings indicate that receational use is not a significant cause of bacterial water pollution, and monitoring shows that turbidity and dissolved oxygen concentrations are also unaffected by recreational use. Campers did contribute to bacterial pollution in the watershed, but the amount contributed from each campground was insignificant in terms of the established water quality standards. Recommendations are made for different types of campgrounds.

Activity: human disturbance.

Impact: change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen; change in levels of nutrients.

Babcock, W.H. 1982. Tenmile Creek - a study of stream relocation. Colorado Div. of Wildl., Spec. Rept. No. 52. 23 pp. (ADF&G, Habitat Library, #B4061.)

After input from various interested agencies, 3 mi of creek were relocated to facilitate the construction of Interstate 70 through Tenmile Canyon west of Denver. The 0.5 million dollar project was designed to provide fish habitat of equal value to that present before construction or, if possible, to improve this habitat.

Construction techniques were designed to minimize damage to flora and fauna. After the channels were excavated, rock and log fish habitat structures were constructed.

Two years after construction, a 4% chance of flood occurred at the project area, which made almost 75% of the habitat structures ineffective. Pool-riffle ratios and quantity and quality of spawning areas remained essentially unchanged throughout the period. Population estimates indicated an increase in the number of fish in the postconstruction period compared to preconstruction numbers. Fish biomass estimates for the project area were comparable for the two periods. Aquatic invertebrate populations were unchanged as indicated by comparison of three pre- and postconstruction indices. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Babcock, M.M. 1985. Morphology of olfactory epithelium of pink salmon, Oncorhynchus gorbuscha, and changes following exposure to benzene: a scanning electron microscopy study. In J.S. Gray and M.E. Christian- sen, eds., Marine biology of polar regions and effects of stress on marine organisms. London: John Wiley & Sons. (ADF&G, Habitat Library, #R3683.)

The pink salmon fishery is a valuable fishery in Prince William Sound, Alaska, and there is great concern that this resource may be damaged by oil pollution from tankers or discharges from a ballast-water treatment plant near Valdez. Because juvenile pink salmon school along shallow estuarine shorelines of Prince William Sound for several weeks before migrating to oceanic feeding grounds, they are vulnerable to oil pollutants from these sources.

Benzene, a major component of crude oil and the effluent from the treatment plant, is water-soluble and relatively toxic to fish. To determine the histopathological effects of benzene on olfactory rosettes of pink salmon, juveniles were exposed to sublethal concentrations of benzene in seawater. Fish were exposed in seawater to 4.3 ppm benzene for 12 d or to one of four concentrations ranging from 0.15 to 4.40 ppm benzene for 29 d. (The concentration that killed half the fish in 96 h was 8.47 ppm).

After the exposures, olfactory rosettes from the fish were examined with scanning electron microscopy. Rossettes from all fry exposed to benzene had exhausted mucous cells. The olfactory lamellae of fry exposed to greater than 0.51 ppm benzene had altered distribution of cilia. Olfactory lamellae of fish exposed to 4.3 ppm benzene for 12 d had patchy losses of cilia; olfactory lamellae of fish exposed for 29 d to concentrations of benzene less than or equal to 0.51 ppm had a generalized loss of cilia. These differences in cilia loss may indicate regeneration of cilia or different individual responses to benzene.

Exhausted mucous cells and loss of cilia on the olfactory lamellar surfaces could change circulation of water through the olfactory rosettes or otherwise interfere with normal chemosensory reception and consequently affect homing, traditional migratory patterns, feeding activity, and avoidance of predators. (Author's abstract: modified)

Activity: drilling; processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Bachman, R.W. 1958. The ecology of four northern Idaho trout streams with reference to the influence of forest road construction. M.S. Thesis, Univ. Idaho, Moscow. 97 pp. (ADF&G, Habitat Library, #B1756.)

Physiochemical and biological measurements of four trout streams, one of which was being logged, were studied. Turbidity was found to increase during rapid runoff from storms or snowmelt. Sedimentation increased in both riffles and pools. Water temperatures, volume of flow, and water chemistry showed no change from the previous year. The relocation of stream channels away from road fills appeared to reduce the amount of eroded material entering the stream.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials.

Baden, S.P. 1982. Impaired osmoregulation in the shrimp *Palaemon adspersus* exposed to crude oil extract. Mar. Pollut. Bull. 13:208-210. (ADF&G, Habitat Library, #R3865.)

Palaemon adspersus, a shrimp that lives in shallow waters, was the test animal in this study on the effects of North Sea crude oil extracts on osmoregulation. The shrimp is hyper- or hypo-osmoregulating according to ambient salinity and temperature. Exposure of the shrimp to the watersoluble fraction of oil for 34 d significantly reduced its ability to maintain hyper-osmoality. The experiments with different concentrations of the water-soluble fraction show a delay in appearance of the effect for 5 to 12 d. Recovery of the osmoregulatory ability takes 1 to 2 wk. The results indicate that if the shrimp has osmoregulatory problems, it may try to avoid extreme changes in salinity of the medium, and this may change its migration patterns.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in level of salinity; change in levels of hydrocarbons.

Baldes, B.J. 1973. How stream channel alterations affect fisheries values. Pages 569-571 in Proceedings fifty-third annual conference, Western Association, State Game and Fish Commission, Salt Lake City, Utah, July 11-13, 1973. (ADF&G, Habitat Library, #R5118.)

This paper deals with the effects of channelizing a 4,200-ft reach of Montana's Big Spring Creek on streambank stability. The 4,200-ft reach was bulldozed into a 2,200-ft ditch. The author reports that "although considerable damage occurred to Big Spring Creek downstream from the channelization, the most noticeable destruction occurred directly upstream." For the upstream reach, the author compares the rate of bank erosion for a 15-yr period prior to channelization to a 10-yr period following the stream alteration. For a 15-yr period following prior to channelization, erosion accounted for an increase of 3 ft in the bank-to-bank measurement (from 25 to 28 ft in width). However, for the 10-yr period directly following channelization, erosion accounted for a loss of 137 ft of bank, causing the bank-to-bank measurement to change from 28 ft to 165 ft.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; addition of substrate materials.

Banner. A., and M. Hyatt. 1973. Effects of noise on eggs and larvae of two estuarine fishes. Trans. Am. Fish. Soc. 102(1):134-136. (ADF&G, Habitat Library, #R3864.)

In laboratory experiments, eggs and larvae of the fish *Cyprinodon variegatus* and *Fundulus similis* were exposed to moderate and high noise levels. Viability of eggs and larvae of *C. variegatus* was significantly reduced in the noisier tank. Noise was more lethal to embryonic than to larval *C. variegatus*. Growth rates of both species were significantly greater in the quieter tank.
Noise levels normally encountered by these species are probably quite low, because they live in shallow, estuarine areas. Even the noise level in the quieter tank of this experiment was higher than that measured by the authors in the representative habitat. The authors believed that the reduction of noise in the tanks would permit even more rapid growth. The mechanism that brought about the differences in growth and survival and the effective frequency range was undetermined.

Activity: blasting; drilling; human disturbance; transport of oil/gas/water - water; transport personnel/equipment/ material - water.

Impact: increase in hydrostatic pressure or noise.

Barclay, J.S. 1980. Impact of stream alterations on riparian communities in southcentral Oklahoma. USDI:USFWS, FWS/OBS-8/17. 91 pp. (ADF&G, Habitat Library, #B3870.)

This study evaluated the effects of stream channelization and impoundment upon riparian habitat and associated bird, mammal, amphibian and reptile populations. Although fish and freshwater invertebrate populations were not included, effects to aquatic habitat were assessed. A study area selection matrix was developed and used to aid in the final selection of two channelized streams (Rush and Wildhorse creeks) and one impounded stream (Cobb Creek), all major tributaries of the Washita River within grassland ecoregions.

Eight principal survey sites on each of two channelized streams, representative of land uses and channel conditions, plus two sites above (one each on Cobb and Lake creeks) and two below Ft. Cobb Reservior on Cobb Creek, were chosen for study after thorough examination of each stream. Intensive plant and animal surveys were conducted on the sites, scattered along 150 km of the streams, during the summer of 1976 and to a more limited extent throughout the following fall, winter, and spring. Species richness and diversity, community composition and species-relative abundance were among those analyses used to determine and compare ecological conditions. Historical recoreds, maps, and aerial photos were used to determine the changes in land use and channel condition that had occurred since 1871 within the Rush and Wildhorse creek floodplains.

Channelization and land use changes along the two prairie streams resulted in or facilitated extensive loss and degradation of aquatic habitat; complete destructionn of wetlands; nearly complete elimination (86%) of the bottomland forest; accelerated erosion; and reduced plant and animal species richness, diversity, and relative abundance. Current plans for additional channelization of Wildhorse Creek, plus persistent land-clearing activities, should result in the complete elimination of any biologically significant riparian habitats along the two streams within a few years.

Prior to 1940, 81% of the original 12,100 ha of riparian forest and associated 726 ha of wetlands were lost. However, the remaining unchannelized segments today are bordered by 5 to 10% proportionally more area of bottomland forest than are the channelized segments, supporting the conclusion that channelization has been a major factor in elimination of riparian forest along the two streams. Channelization has also resulted in an overall reduction of 31% of the original 1871 channel lengths, and a five- to nine-fold increase in channel capacity due to erosion. The channel loss per channelized segment ranged from 21 to 43%.

Although the data on impoundment effects are conflicting from one life group to another, there appears to be a general tendency toward lower species diversity and higher relative abundance on the downstream sites, which may reflect the stabilized downstream flow. However, despite careful screening for potential project areas and selection of the only appropriate study sites above and below Fort Cobb Reservior, it was not possible to control some conditions and point to possible trends in the biotic communities above and below the impoundment, but it has not been possible to draw definite conclusions concerning the effects of impoundment. (Author's summary: partial)

Activity: channelizing waterways.

Impact: change in turbidity or suspended sediments; addition of substrate materials; introduction or removal of species.

Barrick, L.S. 1984. Kenai riverbank erosion study. ADF&G, Div. FRED. Number 41. Juneau. 82 pp. (ADF&G, Habitat Library, #B6250.)

Based upon field observations and existing literature, the author addresses riverfront development on the Kenai River (Alaska) and the problems of riverbank erosion. The first section of the report identifies existing river corridor conditions in terms of the natural environment and development. The author follows by discussing the relationships between developmental activities and effects on riverine habitats (e.g., removal of vegetation from the streambank, construction of buildings, roads, boat docks, groins, increased boat traffic, and erosion of stream banks). Final portions of the report identify bank protection measures and their maintenance. Factors that should be considered before attempts are made to alter streambanks are identified in the final section of the report, as are materials and designs for bank stabilization structures.

Activity: clearing and tree harvest; filling (aquatic and wetland habitats); grading/plowing; human disturbance.

Impact: change in water temperature; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions; increase in hydrostatic pressure or noise; change in level of dissolved oxygen, nitrogen.

Barstow, C.J. 1971. Impact of channelization on wetland habitat in the Obion-forked Deer Basin, Tennessee, Pages 362-376 in Thirty-sixth North American Wildlife Conference. (ADF&G, Habitat Library, #R5117.)

This study represents a current review of the Obion-Forked Deer Rivers Project (part of the Mississippi River tributaries), which was conducted by the Corps of Engineers. At this time of this study, the project was 32% complete and was temporarily halted by a declaratory suit filed in federal court by four private citizens (J. Clark Akers, et al. vs U.S. Army Corps of Engineers, et al., Civil Action No. C-70-349). The investigation of the completed sections of the ditch system has indicated the following: 1) approximately 60% of previously existing woodland and wetland have been cleared, 2) aquatic habitat (natural lakes, sloughs and swamps) have almost been eliminated, 3) edge habitat has been minimized, 4) soil moisture has been reduced, 5) severe erosion problems have occurred, 6) the frequency and duration of flooding has been reduced (Corps indicated an 80% reduction in flooding has occurred) and 7) direct losses to state wildlife management areas. It is estimated that if the channel project is completed aquatic habitat will be reduced by 95% and forest area by 70%.

Activity: channelizing waterways; draining.

Impact: change in depth or velocity of water; addition of substrate materials.

Barton, B.A. 1977. Short-term effects of highway construction on the limnology of a small stream in southern Ontario. Freshwater Biology 7:99-108. (ADF&G, Habitat Library, #R3810.)

A limnological investigation was carried out to document the effects of constructing a modern highway across a small stream in southern Ontario. During construction, suspended solids increased to as high as 1,390 mg/l but later returned to preconstruction levels of less than 5 mg/l. Similarly, sediment deposition increased tenfold to 0.61 g dry wt/cm^2/d directly below the construction site during stream rechannelization after completion of the culvert. Decreased proportion of organic matter in sediments indicated that they came from the construction site. Sediments were readily removed by freshets and apparently settled out in downstream ponds. There was no change in water chemistry. The standing crop of fish was reduced from 24 to 10 kg/ha immediately below the site. This decrease did not occur further downstream, and fish populations at the affected site returned to original levels after construction. No change in numbers of riffle macroinvertebrates was observed during or after construction. However, there was a noticeable shift in species composition. Invertebrates present during construction activities may have remained in sheltered areas, avoiding sedimentation effects. Evidence from invertebrate sampling in denuded areas around the site strongly suggests that organisms that may have been removed during construction were replaced quickly by drift. (Author's summary)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials.

Barton, J.R., and P.V. Winger. 1973. Rehabilitation of a channelized river in Utah. Pages 1-10 in Hydraulic engineering and the environment. Proceedings of the 21st Annual Hydraulics Division specialty conference, Montana State Univ., Bozeman, MT. (ADF&G, Habitat Library, #R5119.)

On a highway construction project in Utah, several reaches of the Weber River were channelized. Various types of instream rehabilitation structures were installed in the altered reaches in an attempt to alleviate some of the anticipated detrimental affects.

The conclusions resulting from this study are summarized in the following list:

1) After a relatively short time, fish populations were the same in changed and unchanged areas in relation to composition, actual numbers per acre, and population estimates. The fish in the altered areas appeared to be concentrated in the holes near the instream structures.

2) Fish food organisms colonized the channeled areas within a few months, and no differences could be detected between the populations of the changed and the unchanged areas in species composition, diversity, or numbers per square meter.

3) The construction itself and the initially unstable substrate of the altered section caused a marked increase in erosion and turbidity, but these were of relatively short duration and seemed to have little long-term effect on the biology of the area.

4) The water chemistry and water temperature were not altered by the channelization. Temperature was controlled by flow releases from Echo Reservoir.

5) This study indicates that rehabilitation measures taken on the Weber River have been successful in producing holes and riffle areas that were utilized by fish and fish food organisms.

6) The placement of instream rehabilitation structures is a step in the right direction to reclaim altered areas. However, this should not be considered a complete cure for channelization. Channelization should be avoided if at all possible.

7) The structures did not alleviate the following problems associated with channelization: 1) loss of stream length, 2) destruction of the natural aesthetics of the river, and 3) loss in streamside vegetation. More work needs to be done to develop solutions for these problems.

8) Alhough most of the structures used on the Weber River did provide some favorable results, more research needs to be done to develop better and more economical ways of rehabilitating a channelized stream. Different structures should be designed and tested as well as determining correct placement of these structures in the stream. (Author's conclusions)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Barton, D.R., W.D. Taylor, and R.M. Biette. 1985. Dimensions of riparian buffer strips required to maintain trout habitat in southern Ontario streams. N. Am. J. Fish. Mgt. 5:364-378. (ADF&G, Habitat Library, #R5135.)

The relationships between riparian land use and environmental parameters that define the suitability of southern Ontario streams for trout were examined for 40 sites on 38 streams. Weekly observations of maximum and minimum temperature, coarse and fine suspended matter, and discharge were made during June, July, and August 1980. Land use was determined from aerial photographs of each stream. Fish were surveyed at each site during August by electrofishing and seining.

The only environmental variable that clearly distinguished between trout and nontrout streams was weekly maximum water temperature: streams with trimean weekly maxima less than 22°C had trout; warmer streams had, at best, only marginal trout populations. Trout streams tended to have low concentrations of fine suspended solids and a more stable discharge, but so did many of the other streams. Water temperature, concentration of fine particulate matter, and variability of discharge were inversely related to the fraction of the upstream banks covered by forest. Fifty-six percent of the observed variation in weekly maximum water temperature could be explained by the fraction of bank forested within 2.5 km upstream of a site. Other land uses were not clearly related to stream variables, except that high concentrations of fine suspended solids were most often observed in reaches used as pasture.

Analysis of data from sites located within buffer strips yielded a regression relating maximum weekly temperatures to buffer strip length and width. The regression accounted for 90% of the observed variation in water temperature for these sites. The model was verified further by comparisons with observed temperatures at a second set of sites located downstream from buffer strips. (Authors abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation.

Bartsch, A.F. 1960. Settleable solids, turbidity, and light penetration as factors affecting water quality. Pages 118-127 in C.M. Tarzwell, ed. Biological problems in water pollution. Robert A. Taft Sanitary Engineering Center, Cincinnati, OH. (ADF&G, Habitat Library, #R2910.)

This paper is a literature review of the title subject as pertaining to water pollution criteria adopted by several control agencies.

The author stresses that "settleable solids, turbidity and light are so interrelated as to require additional discussion as a single factor affecting the environment."

Settleable solids include inorganic particles from soil erosion, mining, dredging, gravel and coal washing, ore concentrating, precipitating industrial dusts, and irrigation. Particles that settle on the bottom can destroy fish-food organisms, interfere with successful hatching of fish eggs, obliterate otherwise suitable spawning areas, and carry unstable organic matter to the bottom, where undesirable decomposition products are formed. While suspended, particles in sufficient concentration or of sufficient hardness and size may directly injure fishes and fish-food animals. Two specific cases involving sizable bodies of marine environment (Chesapeake and San Francisco bays) are cited which were subjected to siltation from mining activity within the watersheds. The effects of improper logging operations in North Carolina were identified as the source of sediment that covered pools and riffles with a layer of unproductive sand up to 10 in thick. Studies conducted in the Powder and Burnt rivers of Oregon found that suspended sediments, originating from gold-dredging operations increased turbidity from a natural level of about 5 ppm to 1,700 ppm. Concurrent declines of fish-food organisms, as well as rainbow trout and whitefish, occurred and were replaced by species more resistant to suspended sediments (suckers).

Decay-resistant organic matter is noted as causing unique problems where these materials accumulate on the bottom of water bodies. Cited specifically are wood fibers lost in the process of pulp and paper making. Under certain conditions, large mats of wood pulp material have been documented to float to the surface of rivers in Wisconson, Ontario, and Main; in one instance the mat formed was 2.5 ft thick and 20 mi long.

In one cited study, fertile salmonid eggs in gravel were exposed 2-4 h on selected days to water containing 1,176-1,330 ppm of suspended solids from a gold-dredging operation. The principal effect noted was reduction in average yield of fry from 16.2% in normal hatchery water to an average 1.16 % in silt-bearing water. This work also demonstrated that the earlier in the incubation period the silt was applied, the greater was the reduction in fry yield, which finally reached zero. Undeveloped eggs were found to be coated and preserved with silt.

Suspended particles also affect the optical properties of water so as to create turbidity. By impairing light penetration, turbidity diminishes the thickness of the euphotic zone and this limits basic productivity. Rates of photosynthesis in relation to light extinction in a raw sewage stabilization pond and in the Ohio River are discussed. Quantities of phytoplankton in clarified and turbid waters of the Missouri River are another expression of impairment of basic productivity by turbidity. Turbidity may also affect temperature relations.

No quantitative information is presented, but the presumption is stated that turbidity limits the distance at which sport fish can see the lure and thus affects both the yield and attractiveness of sportfishing waters.

Activity: clearing and tree harvest; dredging; grading/plowing; processing lumber/kraft/pulp; processing minerals; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Battershill, C.N., and P.R. Bergquist. 1982. Responses of an intertidal gastropod to field exposure of an oil and a dispersant. Mar. Pollut. Bull 13(5):159-162. (ADF&G, Habitat Library, #R3648.)

Field observations have been made of short-term acute and long-term sublethal responses of Nerita atramentosa melanotragus to experimental applications of Maui Condensate and a relatively new oil dispersing agent, Shell SD LTX. Short-term responses suggested condensate/dispersant mixtures were highly toxic, whereas weathered condensate and LTX, when applied separately, produced no significant mortality. In the longer term, however, sublethal effects such as changes in wet weight, gonad weight, and abberations in gonad tissue structure were recorded. Ecological implications of these results are discussed. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Beamish, R.J., G.A. McFarlane, J.C. VanLoon, and J. Lichwa. 1975. An examination of the possible effects of Sudbury nickel mining and smelting operations on fishes and the water chemistry of lakes within the Whitefish Lake Indian Reserve. Fish. Mar. Serv. Res. Dev. Tech. Rept. 579. 52 pp. (ADF&G, Habitat Library, #B1212.)

The following water chemistry parameters were determined from lakes within the Whitefish Lake Indian Reserve: pH, alkalinity, sulfate, chloride, nickel, copper, zinc, iron, lead, cadmium, manganese, sodium, potassium, magnesium, calcium, hardness, silicate, total dissolved solids, conductivity, total dissoved nitrogen, suspended nitrogen, total dissolved phosphorus, suspended phosphorus, chlorophyl a. The low pH, high sulfate, and heavy metal content of some lakes indicated that lakes in the reserve have been contaminated as a result of mining activities in Sudbury. In particular, 1) lakes located to the south and west of the reserve had acid concentrations that were harmful to fishes; 2) abnormally high concentrations of heavy metals, particularly nickel, were found in most lakes. Although the observed concentrations were below levels reported to be directly harmful to fishes, they were within the range that has been found to be harmful to other aquatic organisms; 3) the portion of the water system forming the north boundary of the reserve was found to be heavily contaminated in almost all parameters tested. Some of the observed concentrations exceeded internationally accepted limits for drinking water. The high concentrations found from the single location suggested that the entire water system forming the north and west boundary of the reserve was also polluted. The extremely high concentration of nickel from this location indicated that mining activities were at least partially responsible for the contamination of this waterway. A second survey of the five most acidic lakes showed that water chemistry was similar to the initial survey and lakes were indeed acidic. These acidic lakes were found to be relatively deep lakes situated in predominatly soilless drainages indicating the low acidity was not of natural origin. The most acidic lake was surveyed for the presence of fish, and none were captured. (Author's abstract)

Activity: processing minerals.

Impact: change in levels of heavy metals.

Beauchamp, K.A., and M.M. Gowing. 1982. A quantitative assessment of human tramping effects on a rocky intertidal community. Mar. Environ. Res. 7:279-293. (ADF&G, Habitat Library, #R3863.)

The density and diversity of algae and invertebrates in the rocky marine intertidal were studied at three sites (in California) differing in degree of human trampling. Quantitative sampling showed that 1) a general pattern of higher density and diversity occurred at the less trampled sites, 2) the densities of the mussels and barnacles and the diversity of algae were unaffected, and 3) at the most trampled site, the brown alga *Pelvetiopsis limitata* was absent and the small bivalves *Lasaea* spp. were found in lower densities.

Activity: human disturbance.

Impact: alteration of natural cover - aquatic vegetation; physical trampling or crushing; introduction or removal of species.

Bechtel, T.J. 1979. Biological and water quality implications of current crab processing waste disposal practices in Dutch Harbor, Alaska. Pacific Seafood Processors Assoc., Seattle, WA. 38 pp. (ADF&G, Habitat Library, #R2040.)

Waste pile compaction and slumping, microbial degradation, downslope movement, and dispersion are four mechanisms affecting the fate of ground crab wastes discharged into nearshore areas around Amaknak Island. Burrowing and attached marine benthic organisms are completely eliminated from areas that become covered with crab wastes deeper than about an inch. The wastes appear to have a smothering effect on these organisms and do not provide a suitable substrate for recolonization after deposition. Mobile bottom and swimming organisms are attracted to the piles, particularly those containing fresh wastes. The soft-tissue component of the waste provides a food source for these animals. There are no data to evaluate whether the species diversity and relative abundance of the fish and macroinvertebrates or any significant nursery areas have been affected by the wastes.

Observations of marine life around the waste piles indicate that there are not consistent toxic sulfide conditions existing. It appears that the surface of the waste pile remains aerobic but that the interior portions of the pile are anaerobic. Colonization of the pile by marine organisms has not been observed because the shell particles do not provide a suitable substrate for organisms other than those affecting decay.

Evaluation of the screening and barging alternative indicates that deepwater disposal does not provide any substantial water quality and marine biological benefits compared to current waste disposal practices. In fact, there may be some disadvantages with respect to a slower degradation process and a greater amount of bottom area covered with crab wastes.

Activity: solid waste disposal.

Impact: addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of nutrients; artificial attractant to biological organisms.

Becker, C.D., D.A. Neitzel, and D.H. Fickeisen. 1982. Effects of dewatering of chinook salmon redds: a tolerance of four developmental phases to daily dewatering. Trans. Am. Fish. Soc. 111(5):624-637. (ADF&G, Habitat Library, #R3856.)

The effects of redd dewatering on four developmental phases of chinook salmon, Orchorhynchus tshawytscha, were experimentally evaluated using artificial redds during the period September through January at the Pacific Northwest Laboratory, Richland, Washington. The four developmental phases were defined as follows: fertilized egg to eyed egg (designated as cleavage eggs), eyed egg to near hatch (designated as embryos), 24 h before hatch to advanced yolk-sac alevins (designated as eleutheroembryos), and advanced yolk sac alevins to emergence from gravel (designated as pre-emergent alevins). The redds consisted of aquaria containing a gravel mix and supplied with four liters of water per minute at 10C.

Cleavage eggs and embryos (the egg phases) and eleutheroembryos and pre-emergent alevins (the alevin phases) were dewatered 20 consecutive times in 22-d tests. The egg phases were considerably more tolerant than the alevins. In order, from least tolerant to most tolerant, were pre-emergent alevins, eleutheroembryos (yolk-sac alevins), cleavage egg, and embryos. Some cleavage eggs were killed by 12-and 16-h daily dewatering (50% survived 20 successive 12-h dewaterings, and 30% survived 20 16-h dewaterings). However, mortality probably was not due entirely to dewatering but also to high temperatures that resulted from insolation. Mean daily intergravel temperatures were highest in redds dewatering 16 h; these redds also showed greatest mortality. Embryos survived up to 22-h dewaterings. Embryos also tolerated extended, multiple dewaterings (over 60% survival for four consecutive 118-h periods) and one-time, continuous dewatering for up to 12 consecutive days (over 80% survival). In contrast, approximately half the eleutheroembryos were killed by 4-h daily dewaterings, and nearly all pre-emergent alevins were killed by 1-h daily dewaterings. The tolerance of the-alevin phases to dewatering probably decreases with the formation of functional gills and vascular system for uptake of dissolved oxygen from water.

Intergravel temperatures were affected by insolation and air temperature. Intergravel temperatures increased to lethal levels during dewatering of cleavage eggs in early fall and limited their survival. Growth of egg phases from some females was retarded by dewatering, but this phenomenon was not consistent for all egg groups. The size of surviving eleutheroembryos decreased as the length of daily dewatering periods increased.

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water.

Beland, R.D. 1953. The effect of channelization on the fishery of the lower Colorado River. Calif. Fish and Game 39(1): 137-139. (ADF&G, Habitat Library, #R5091.)

In the lower end of Mohave Valley of the Colorado River drainage, a major portion of marsh area (4,300 surface acres of still water) containing many lakes and sloughs was drained after the Bureau of Reclamation completed a program of channelization and marsh drainage for flood control purposes. The marsh area was drained by a 10-mi channel, approximately 17 ft in depth, 250 ft in width, having maximum carrying capacity of 75,000 ft/s. This project decreased the value of the Colorado River as a habitat for game fishes because it 1) drained the adjoining backwater lakes and sloughs, 2) eliminated riparian vegetation cover, 3) eliminated the eddies and "holes" along the river littoral zone, 4) increased water turbidity, 5) increased bank erosion, and 6) reduced the amount of spawning area.

Because little could be undertaken in this area to rectify the losses to the fishery, it was recommended that the Bureau of Reclamation compensate for damages by improving fishing conditions in other portions of the river when the need arose. It was also recommended that, wherever feasible, channelizing operations be modified so that a maximum area of lake and slough habitat remains open to the river.

Activity: channelizing waterways; draining.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fisheries - Engineering Research Program, U.S. Army Corps of Engineers, North Pacific Division, Portland, OR. 290 pp. (ADF&G, Habitat Library, #B5944.)

This handbook was designed for use by engineers and biologists employed in dealing with design problems of fish facilities and in the operation of existing facilities (e.g., hatcheries, fishways, fish passes, and fish ladders). The handbook sets forth limits that may be used in design for estimating facilities sizes, water requirements, general costs, and operating procedures. From the standpoint of impacts, the handbook contains chapters that discuss the impacts to fish from factors such as water temperature, silt and turbidity, metals, plastics, pesticide and herbicides, culverts, channel changes, fish passage through turbines, spillways and conduits, and fishway structures at dams.

Activity: channelizing waterways; chemical application; clearing and tree harvest; dredging; grading/plowing; processing minerals; stream crossing - structures; water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of physical barriers - partial obstructions; increase in hydrostatic pressure or noise; impingement or entrainment or entanglement; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of biocides; change in levels of other toxic compounds - other.

Benke, A.C., D.M. Gillespie, and F.K. Parrish. 1979. Biological basis for assessing impacts of channel modification: invertebrate production, drift, and fish feeding in a southeast blackwater river. Georgia Inst. of Tech. Atlanta, Georgia. (ADF&G, Habitat Library, #B6317.)

The production dynamics of invertebrates in the Satilla River, a blackwater river in the southeast United States, were studied to obtain an understanding of their functional role in the river ecosystem and to utilize the information for better river management. The invertebrates occurred in three major habitats: submerged wooden substrates, or "snags"; the sandy benthic habitat of the main channel; and the muddy benthic habitat of backwater areas. Three independent approaches were utilized to determine the relative importance of these habitats: 1) quantitative samples of invertebrates were used to estimate animal production in each habitat, 2) invertebrate drift dynamics were studied, with particular concern for the habitat origin of the animals, and 3) the use of invertebrates as prey by the major fish species was studied to establish trophic pathways and the habitat origin of the prey.

The greatest diversity of species, standing stock biomass, and production occurred on the snag habitat. The major colonists of snags were filter-feeding insects, particularly net-spinning caddisflies, blackfiles, and midges. Dragonfly, stonefly, and hellgrammite larvae were the major invertebrate predators. Total invertebrate production values of from 57 to 72 g dry wt/m^2 of snag surface are among the highest in running waters. Benthic organisms (both in sand and mud) consisted primarily of midges and oligochaetes, and due to an extremely high production/biomass ratio (especially in the sandy benthos), benthic production was from 14 to 28 g dry wt/m^2.

Drift, or the downstream transport of these animals in the current, was shown to be an important aspect of the dynamics of at least the snag organisms. Roughly 80% of the numbers and biomass of animals found in the drift originated from the snags. Drift activity was high throughout the year but particularly so in the summer. All insect groups drifted mostly at night, especially just after dusk. Drift densities (roughly 3/m^3) were high in comparison to most streams, another indication of high invertebrate productivity for the system. Furthermore, the percentage of snag animals in the drift at a given point in time was extremely high, often in the vicinity of 1%.

The major fish species in the river were sampled by electrofishing at six times throughout the year in order to analyze stomach contents. The major game species were sunfishes (Centrarchidae), especially redbrest and bluegill sunfishes, and largemouth bass. An important nongame species was the spotted sucker. Most of the insectivorous sunfishes were greatly dependent upon the snags as a source of prey organisms, with relatively little feeding on the benthos. Spotted suckers fed fairly evenly among the three major habitats, while sarmouth (a sunfish) primarily utilized crayfish as food. Bass fed upon crayfish and "forage" fishes (i.e., minnows, etc.), and pickerel consumed forage fishes almost exclusively. The forage fishes relied upon benthic insects and drifting terrestrial arthropods.

The invertebrate production and drift and fish-feeding analysis provide an integrated and consistent picture of invertebrate dynamics in this blackwater river. The snag habitat was clearly the most productive in terms of number of species and biomass. Futhermore, snags were the source of most of the drift organisms, as well as food for several important fish species. Recognition of the role of snags in river ecosystems has strong management implications. The removal of such substrtes, or "snagging," (along with even greater alterations such as clearing and channelization) is likely to cause a significant decline in overall animal diversity and productivity. Removal of snags and their associated filter-feeding animals may also affect the river's ability to assimilate particulate organic matter, either natural or man-introduced. In previously "snagged" rivers, the introduction of wooden substrates is likely to enhance biological productivity.

Activity: channelizing waterways.

Impact: removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation; introduction or removal of species.

Benson, N.G., and A.S. Weithman. 1980. A summary of seven U.S. Fish and Wildlife stream channelization studies. USFWS, Eastern Energy and Land Use Team, Office of Biol. Ser. 54 pp. (ADF&G, Habitat Library, #B1883.)

Studies on the effects of stream channelization on fish and wildlife populations and habitats were conducted in Iowa, Vermount, Montana, North Carolina, Ohio, Indiana, Wisconsin, and Mississippi from 1973 to 1977. This report synthesizes the information developed in those studies for use in impact assessment and for the development of mitigation methods. The streams included cold water trout streams, warm water streams in the midwest and midsouth, and coastal swamp streams. Channelization resulted in direct loss of aquatic and riparian habitat and reduction in habitat diversity. Major physical effects of channelization were decreases in sinuosity and stream length, increases in gradient and flow rates, and decreases in particle sizes in stream bottom substrates. Macroinvertebrate abundance and diversity generally decreased after channelization, but recovery was rapid when only short segments of stream were altered; recovery with time was directly related to the recovery of the stream substrate. Fish numbers and biomass generally declined after channelization, and species compostion always changed. Fish populations benefited from in-stream mitigation structures on altered streams in Montana and Ohio. Mammal and bird populations along channelized streams were controlled by the amount and type of riparian vegetation and were usually lower than along natural streams. Reptile and amphibian abundance and diversity were controlled by the amount of sheet water habitat in the riparian zone. With adequate mitigation, streams returned to a condition comparable to an unaltered stream, but a section of the Luxapalila River, Mississippi, had not recovered much in 60 yr. Recommendations for assessing impact and developing alterative measures in stream channelization emphasized the need to maintain habitat diversity and to utilize and properly design mitigation structures. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; addition of substrate materials.

Bernard, F.R. 1976. A selected bibliography on the biological effects of ocean dumping. Fish. Mar. Serv. Res. Dev. Tech. Rept. 628: 22 pp. (ADF&G, Habitat Library, #B6110.)

This report presents a selected review of literature that pertains to the management and interpretation of the Canada Ocean Dumping Act. The author identifies the following six areas where information is necessary for proper management of ocean dumping:

1. Development of an understanding of the behavior and characteristics of waste substances in the marine environment, with special attention to toxicity, uptake, and concentration in foodchains, and possible synergistic effects

2. Development of techniques to monitor effects of wastes in marine ecosystems, both planktonic and benthic, and establishment of specific criteria for commonly released wastes

3. Development of information to govern the selection and designation of dumping sites, their absorptive capacity, and effect of dumping with a view to permit cancellation or limitation should ongoing monitoring suggest adverse ecological impact

4. Development of a protocol for ongoing monitoring of dumping sites to check for possible permit contravention by user

5. Exploration of alternatives to ocean dumping

6. Establishment of a centralized biological data bank for reporting and recording ocean dumping activities and making biological interpretation available to management

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals.

Beschta, R.L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resour. Res. 14(6):1011-1016. (ADF&G, Habitat Library, #R2296.)

Suspended sediment production after road construction, logging, and slash disposal was significantly increased on two watersheds in Oregon's Coast Range. A 25% patch-cut watershed showed increases during three of eight posttreatment years. These increases were caused primarily by mass soil erosion from roads. Monthly sediment concentrations before the occurrence of the annual peak flow were increased more than those following the annual peak. Surface erosion from a severe slash burn was the primary cause of increased sediment yields for five posttreatment years on a watershed that was 82% clear-cut. Monthly sediment concentrations were generally increased throughout the winter runoff period on this watershed. The flushing of suspended sediment in Oregon Coast Range watersheds is apparent from seasonal changes of suspended sediment rating curves.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

Beschta, R.L. 1979. Debris removal and its effects on sedimentation in an Oregon Coast Range stream. Northwest Sci. 53(1): 71-77. (ADF&G, Habitat Library, #R2302.)

In the early 1960's, roadbuilding and logging began in the Mill Creek drainage of the Oregon Coast Range. As a consequence, debris accumulations began at that time and continued until 1975, finally resulting in the blockage of upstream migration of anadromous fish. In 1975, the large debris dams were removed by cable yarding, tractors, and hand crews.

Turbidity and suspended sediment concentrations were monitored above and below the debris removal sites. Daily discharge averaged 93% of the 15-yr average for the peak runoff period.

Upstream from the debris obstruction, substantial amounts of sediments had collected during the course of active logging and road building. Removal of the debris triggered localized scouring of sediment deposits, which was relatively minor. Immediately downstream from the removal site, however, several pools began to fill in with silt and sand-sized particles. Turbidities at the sampling station above the removal site never exceeded 30 Nephlametric Turbidity Units (NTU), whereas turbidities below exceeded 100 NTU. This increase was caused by scouring of the sediment previously stored in the channel. Within 3 mo of debris removal, turbidities above and below the removal site equalized at 50 NTU, indicating that the channel system had nearly stabilized.

Over the period of study, the material making up the substrate of the study stream was reduced from sandy-silt to relatively coarse sediments (e.g., cobbles and boulders). An estimated 5,250 m^3 of sediment eroded from 250 m of channel, and the fate of this material is unknown.

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials.

Beschta, R.L. 1980. Turbidity and suspended sediment relationships. Pages 271-282, in, Proceedings of Watershed Management Symposium, Irrigation and Drainage Division, Am. Soc. Civil Eng., Boise, ID. (ADF&G, Habitat Library, #R2929.)

Turbidity and suspended sediment concentrations were analyzed for streams draining three forested watersheds in western Oregon. At the Oak Creek and Flynn Creek watersheds, suspended sediment concentration and turbidity correlated significantly (90% confidence level) for 24 of 26 storm events, confirming suspended sediment as the most important factor influencing the turbidity of Oregon's Coast Range streams. Correlations developed for an individual period of storm flow, however, usually differed significantly from correlations for other stormflow periods. Furthermore, relationships between suspended sediment and turbidity were significantly different between drainages, illustrating that prediction equations must be developed on a watershed-by-watershed basis. At Oak Creek, the correlation between suspended sediment and turbidity did not differ significantly from year to year over a 3-yr period. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments.

Bethlahmy, N. 1967. Effect of exposure and logging on runoff and erosion. USDA: Forest Service, Intermountain For. & Range Exper. Stat., Res. Note INT-61. Ogden, UT. 7 pp. (ADF&G, Habitat Library, #R5176.)

High-intensity rainfall was applied artificially to plots on eight steep, forested areas in the Payette National Forest in central Idaho. Logged and unlogged sites on northeast and southwest exposures were represented equally. Results show that runoff and erosion are greater on southwest than on northeast exposures and that even after careful logging, erosion increases on southwest but not significantly on northeast exposures. (Authors abstract)

Activity: clearing and tree harvest.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Beyer, D.L., R.E. Nakatani, and C.P. Staude. 1975. Effects of salmon cannery wastes on water quality and marine organisms. J. Water Pollut. Control Fed. 47(7):1857-1869. (ADF&G, Habitat Library, #R3583.)

The impact of cannery wastes on marine ecology and water quality at Petersburg, Alaska, was investigated during the 1971 canning season. The following are the significant findings of the study. 1) Cannery wastes did not appreciably affect dissolved oxygen (DO). The DO values decreased from an average of 13 mg/l at the beginning of the season to 7.5 mg/l during the latter part. However, preliminary results indicate that this sharp decrease was caused more by a decline in phytoplankton abundance, light intensity and duration, and increasing periods of cloudiness rather than by the effects of cannery wastes. 2) Strong currents flushed most wastes from Petersburg harbor, but some temporary accumulations occurred near discharge vents. 3) Benthic organisms generally avoided areas of waste accumulation, but samples collected immediately adjacent to the accumulations showed a wider variety of species. 4) Scavengers such as fish and birds actively consumed wastes from the discharge plume. 5) Turbidity, pH, DO, biological oxygen demand, and temperature readings demonstrated a rapid dilution and dispersion of wastes.

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness.

Bianchi, D.R., and R. Marcoux. 1976. The physical and biological effects of physical alteration on Montana trout streams and their political implications. In Proceedings, symposium on stream channel modification. August 15-17, 1975, Harrisonburg, VA. (ADF&G, Habitat Library, #R5143.)

In 1973, 160 mi of six streams were surveyed, and it was determined that 24 mi of channel and 44 mi of stream bank were altered. Also, trout populations were determined on three adjacent sections on the Ruby River with different amounts and types of alterations. There were approximately three times as many brown trout in a natural section as compared to a bulldozed section and two times as many as compared to a riprapped section. This information was used to help pass the Natural Streambed and Land Preservation Act of 1975. The act goes into full effect on January 1, 1976.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; alteration of natural cover - overhanging bank or shoreline.

Bias, V.R. 1981. Cadmium uptake rates in euryhaline amphipods of the Elbe Estuary: experiments with Corophium volutator (Pallas) (Amphipoda, Corophiidae). Arch. Hydrobiol., Suppl. 61. (In German, with English abstract and summary.) (ADF&G, Habitat Library, #R3884.)

Indications that cadmium has a long biological half-life and a high toxicity provided reason for an investigation of the kinetics governing the accumulation and elimination of this heavy metal. The aim of this study was to determine the distribution pattern of cadmium added intermittently to a system of water-sediment-organisms. The experimental conditions were varied (sediment type, salinity, cadmium concentration) in order to obtain some detailed information on the complex reaction in the accumulation processes following the introduction of cadmium into an ecosystem, such as the Elbe estuary.

The accumulation in the test organism, Corophium volutator, kept in waters of different salinities followed a linear curve for 92 h at concentrations up to 30 ug Cd/l. At higher concentrations, the corresponding accumulation rates decreased with time, indicating that saturation was being approached. Salinity influenced the accumulation rate. At identical cadmium concentrations the resulting accumulation was greater at lower salinities (4 ppt) than at higher values (up to 28 ppt S). The ratio of the accumulation rates at 4 ppt and at 28 ppt S is 4:1.

In long-term experiments with quartz-sand sediment of known particle size, the adsorption capacity of the fine-grain sediment (63-125 um) proved to be superior to that of coarse-grain sand and gravels (250-500 um). Substantial reduction of the cadmium concentration due to adsorption resulted in an intermittent reduction of the cadmium-accumulation rate in Corophium. (At initial concentrations of 3.0 mg Cd/l in the system and volume ratios, water to sediment, of 3.6:1.0, the amount removed from the water by sediment of 63-125 um particle size equalled 60-80%). Natural sediment from the Elbe mud flats, under similar conditions, effected a decrease of cadmium concentrations in the water by two or three orders of magnitude. The adsorption of cadmium by the sediment was greater at low (4 ppt S) than at high salinity (-28 ppt S).

The accumulation of cadmium in Corophium volutator proved to be predominantly dependent on the concentration in the water. The sediment-bound cadmium seemed to be unavailable or not readily available to the test animals.

In parallel tests with the same amount of cadmium per system, salinities were maintained at various values from 4 to 20 ppt. The concentration in all test animals was of the same magnitude. The greater adsorption by the sediment at low salinity is fully compensated for by a more intensive accumulation in the organisms.

In the experiments with mud-flat sediment, cadmium was usually administered as a single dose after the test animals had become adapted to the experimental habitat. Under these conditions, a characteristic three-phase accumulation pattern was observed:

1) At the beginning, a steep increase in cadmium content, lasting from 24 h to 4 d, results from high concentration. During this, time the rate of accumulation decreases.

2) Over a period of 4 to 8 d, and sometimes as much as 14 days, the elimination rate exceeds the accumulation rate until the concentration in the water approaches a constant value.

3) Accumulation resumes, leading to an increasing cadmium content in the animals over a long period of time (6 wk to 3 mo). The rate levels off gradually.

However, when the crustaceans were introduced after the cadmium had established an equilibrium in the system (4 wk after dosage) the resulting accumulation was linear over the entire experimental period of 43 d. Therefore the three-phase accumulation pattern is interpreted as the organism's reaction to the changes in the cadmium concentration in the water.

Application of discrete quantities of cadmium at the beginning of a test, or, alternatively, in several portions at intervals of a few days, did not bring about significantly different accumulation values in the Corophium.

In elimination experiments, the water containing cadmium was exchanged for uncontaminated water. After single or multiple water changes, the original cadmium concentrations, present before water renewal, were reestablished within a few days due to leaching from the sediment. Thus, following each water change, elimination of cadmium occurred only for a short time. Accumulation in the organisms continued as the concentration in the water rose.

Regardless of the conditions during accumulation (with or without sediment), the elimination in uncontaminated media never exceeded 50% of the total absorbed. The most significant loss of cadmium occurred only during the first 7 d. Desorption is the most important mechanism of elimination.
At optimum salinity (16 ppt) in experiments with and without a nutritional source, concentration factors of 900-1,000 were obtained. These are in the same order of magnitude as for the Corophium population in the Elbe estuary, calculated on the basis of water analyses to be 0.14 - 0.56 ug Cd/l. From this comparison, the conclusion can be drawn that cadmium accumulation from ingested material is of secondary importance in the natural habitat as well.
Differences in accumulation by adult amphipods according to their size could be neglected. In contrast, juvenile animals accumulated significantly higher concentrations than adults. No

significant differences in cadmium concentrations were found when males and females were compared.

Large amounts of cadmium resulting from posthumous intensive uptake, as repeatedly reported in literature, could not be detected in Corophium. Analyses of dead but still undecomposed animals revealed cadmium concentrations similar to those in living specimens.

Toxicological phenomena could be already observed at concentrations in the water of about 10 ug Cd/l. The crustaceans exhibited increased irritability. On the other hand, concentrations above 30 ug Cd/l caused a depressed reactivity. At concentrations greater than 100 ug Cd/l mortality increased. Ecological implications, affecting the intertidal mud flats, could be expected from an extended recycling of cadmium because of its high mobility at the water-sediment interface. Another potential hazard involves peak concentrations, even if these are of short duration. Because the shrimps have only a limited capability to eliminate cadmium, high concentrations would remain in their tissues long after even a short-term exposure. (Author's summary)

Activity: dredging; processing minerals; solid waste disposal.

Impact: change in levels of heavy metals.

Birtwell, I.K., G.F. Hartman, B. Anderson, D. J. McLeay, and J.G. Malick. 1984. A brief investigation of arctic grayling (Thymallus arcticus) and aquatic invertebrates in the Minto Creek drainage, May, Yukon Territory: an area subjected to placer mining. Can. Tech. Rept. Fish. Aquat. Sci. 1287. 57 pp. (ADF&G, Habitat Library, #B5060.)

The distribution and abundance of fish in the Minto Creek drainage, Mayo, Yukon Territory, was investigated between August 6 and 10, 1982. The study was carried out to obtain preliminary information on the effects of placer mining on the distribution, feeding, and condition of arctic grayling (Thymallus arcticus).

Underyearling arctic grayling were abundant in the clear waters of Minto Creek above the confluence with Highet Creek - a tributary stream subjected to active placer mining. Only one underyearling fish was captured from two sites in Highet Creek during active placer mining, whereas in the clear unmined tributary creeks (Bennet, Roaring Fork, and Mud) higher numbers of underyearling arctic grayling were captured with less sampling effort. The number of grayling captured increased progressively downstream.

Significantly higher condition factors were recorded for under-yearling arctic grayling in the clear tributary creeks compared with those in Minto Creek. Older grayling were found primarily in the lower sections of the drainage in both turbid and clear waters.

The highest density but lowest number of taxa of invertebrate drift organisms occurred in Highet Creek and was dominated by chironomid larvae. The greatest number of taxa in invertebrate drift samples occurred at sites that were not affected by placer mining

Arctic grayling in unmined tributaries to Minto Creek and in Minto Creek upstream of the mined tributary had consumed the greatest number and diversity of prey items, relying primarily on dipteran, ephemeropteran, and trichopteran larvae. Arctic grayling in Highet Creek consumed few prey items, mainly dipterans. The scarcity of fish in the turbid stream being mined (which had the highest density of chironomid larvae) implies that factors other than food were responsible for the observed distribution.

It is concluded that a major part of the Minto Creek drainage is used by arctic grayling but that placer mining activities tend to confine underyearlings to the less turbid waters.

Activity: dredging; processing minerals.

Impact: change in turbidity or suspended sediments.

Bishai, H.M. 1961. The effect of pressure on the survival and distribution of larval and young fish. J. Cons. Int. Explor. Mer. 26(3):292-311. (ADF&G, Habitat Library, #R3601.)

The purpose of this study was to find an explanation for the behavior of the early larval stages of fishes under natural conditions. Such early stages - which are considered critical in the life of a fish - may react differently to the various factors as compared with older stages.

Results show that newly hatched herring larvae (6.5-8 mm) and salmonid alevins can live at pressures as high as five atmospheres (a depth of about 40 m) and that they are apparently not affected by compression, either quick or slow. However, young salmon and brown trout (98-178 d old) die within 24 h when subjected to an increase of pressure of more than 15 cm Hg (0.19 atmosphere). This is difficult to explain, because at this stage the young fish have a well-developed open swim bladder. Several experiments were carried out at this life stage - subjecting the fish to an increase of pressure of more than one atmosphere - and in all cases the fish died. Death due to supersaturation of water was ruled out.

Later stages of salmonids (older than 178 d) are not affected under the same conditions by the increase of pressure. It is concluded that the reaction of young salmonids towards the increase of pressure depends on the age of the fish. Whereas the alevins are not affected until the absorption of the yolk-sac, young fish from 98 to 178 d old are affected, whereas older stages are not affected.

Young plaice (3.7-5 cm) tolerate pressures at least as high as 2 atmospheres (higher pressures were not investigated). Plaice do not have a swim bladder and thus are not affected by the increase of pressure.

It is concluded that the effect of pressure on the survival and distribution of larval and young fish depends on the species, the age of the fish, and the presence or absence of a swim bladder.

Activity: blasting; water regulation/withdrawal/irrigation.

Impact: increase in hydrostatic pressure or noise.

Bishop, C.T., B. DeYoung, V.W. Harms, and N.W. Ross. 1983. Guidelines for the effective use of floating tire breakwaters. Cooperative Extension Information Bull. 197. Cornell Univ.,Ithica, N.Y. 19 pp. (ADF&G, Habitat Library, #R3883.)

This document provides current information on the effective use of floating tire breakwater (FTB) technology. The objectives of this document are to 1) help managers of coastal facilities assess the feasibility of FTBs; 2) assist regulatory authorities in evaluating FTB applications; 3) inform FTB designers and building contractors of current technology and research information; and 4) help university and industry-based investigators identify existing FTB technical information and research needs.

The authors orient the document towards potential users of FTBs. Specific technical references are cited in the text. (Authors' introduction: modified)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; addition of physical barriers - partial obstructions; change in level of salinity.

Bisson, P.A., and J.R. Sedell. 1984. Salmonid populations in streams in clearcut vs. old-growth forests of western Washington. Pages 121-129 in W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley, eds. Proceedings of a symposium, fish and wildlife relationships in old-growth forests. Juneau, Alaska, April 12-15, 1982. (ADF&G, Habitat Library, #R5124.)

Cutthroat trout, juvenile steelhead trout, and juvenile coho salmon were sampled during the low-flow period of summer to compare population biomasses in western Washington streams flowing through old-growth forests with those in areas recently clear-cut. In paired logged and unlogged sites, total salmonid biomasses averaged 1.5 times greater after logging than in adjacent unlogged sections. Among all sites (paired plus unpaired locations), total salmonid biomasses were 2.0 times greater, on average, in clear-cuttings. Streams in logged watersheds contaianed higher percentages of age-0+ steelhead and age-0+ cutthroat trout and lower percentages of age-0+ coho salmon and age-1+ and 2+ cutthroat compared to streams in old-growth forests. Shifts in species and age composition were related to habitat changes that resulted from timber harvesting and debris removal from the channels. Large, stable organic debris delined and unstable debris increased after passage of forest practices legislation that mandated immediate debris removal from the channels. Large, stable organic debris declined-and unstable debris increased after passage of forest practices legislation that mandated immediate debris removal following logging. Pool volumes decreased and riffle volumes increased after streambank disturbances and channel clearance, although the frequency (number of km) of both pools and riffles was lower in streams flowing through clear-cut sites. Riffles in streams that underwent extensive debris removal were elongated and in many cases extended through former pool locations. Increases in the proportional abundance of underyearling steelhead and cutthroat trout after clear-cutting is possibly explained by the preference of these fishes for riffle habitat, while the relative decline of coho and older cutthroat may have resulted from the loss of pool volume and large, stable debris for cover. (Author's abstract)

Activity: clearing and tree harvest.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Bjornn, T.C., M.A. Brusven, M. Molnau, F.J. Watts, and R.L. Wallace. 1974. Sediment in streams and its effects on aquatic life. Res. Tech. Completion Rept., Proj. B-025-IDA, Idaho Water Resources Res. Inst., Univ. Idaho, Moscow, ID. 47 pp. (ADF&G, Habitat Library, #R2931.)

A team of investigators from the disciplines of engineering, entomology, and fisheries cooperated in a study to assess the temporal and spatial impact of decomposed granite bedload sediment on insect and fish populations and on the capability of mountain streams in the Idaho batholith to transport this sediment. This investigation was designed to provide information for resource managers who formulate watershed management guidelines for streams of the Idaho batholith and other areas with granitic base rock.

Three approaches were used in the study:

1) Correlation surveys - Natural streams in the Idaho batholith were surveyed to correlate the amount of sediment in the substrate with sediment movement, standing crop of insects, numbers of drifting insects, and the distribution and abundance of juvenile chinook salmon, <u>Oncorhynchus tshawytscha</u>, and steelhead trout, <u>Salmo gairdneri</u>.

2) Experimental channels - Artificial channels and controlled variables to test experimentally the effects of various levels of riffle sedimentation on the distribution and abundance of insect and fish populations.

3) Addition of sediment to natural streams - Sediment was added to both riffles and pools in a study stream during the summer low flow to assess the effects of large amounts of sediment on fish and insects in a stream with small amounts of naturally occurring sediment already present. Physical characteristics of the stream were assessed, and changes in the fish and insect populations before, immediately after, and 3 wk subsequent to the sediment additions were monitored.

Data collected from stream surveys, channel experiments, and sediment addition to a natural stream indicated that juvenile chinook salmon and steelhead trout were not adversely affected during the summer when there was a large amount of sediment in the riffles. Insect densities (drift and benthos) were smaller in riffles of natural streams with large amounts of sediment, but decreased densities of insects were not reflected in population densities or size of the fish.

Reduction of pool area or volume with sediment in small streams will likely result in reduction in summer capacity of a stream for fish proportional to the percentage of pool area or volume lost.

In the tests with fully sedimented riffles during the winter, fewer age-0 steelhead trout and chinook salmon remained in the channels with sediment than in the ones without sediment because these fish normally entered the crevices in the substrate during winter and were not able to do so in sedimented riffles. Larger juveniles resided in pools during the winter and were not affected by sediment in the riffles.

Insect abundance was not decreased by adding sediment to riffles in the test channels or by adding sediment to a short section of a natural stream. Insect species diversity decreased temporarily in both test channels and the natural stream after sedimentation of riffles, but there was no measurable effect on the density of benthic or drifting insects one or more days after sedimentation. (Executive Summary: modified)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

Bjornn, T.C., M.A. Brusven, M.P. Molnau, J.H. Milligan, R.A. Klamt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. Univ. Idaho, Moscow. Forest, Wildlife and Range Experiment Station, Bull. 17. 43 pp. (ADF&G, Habitat Library, #R2932.)

This report discusses the transport of granitic bedload sediment (less than 6.35 mm diameter) in streams flowing through central Idaho mountain valleys and the effects of sediment on the density, distribution, behavior, growth, and food habits of juvenile chinook salmon and steelhead and cutthroat trout. Further studied concerned the abundance of insect organisms used as food by these fish species.

Laboratory stream channels and batholith streams were employed to study benthic insect community tolerances for different levels of sediment pollution. Substrate characteristics such as level of cobble imbeddedness, predominant substrate, and size of substrate surrounding cobble were correlated with species-specific and community changes.

Results indicated that survival and emergence of salmonid embryos begins to decline when the percentage of fine sediment in spawning riffles exceeds 20 to 30%. When riffles are fully imbedded with fine sediment, insect species composition and abundance changes. Summer rearing or winter holding habitat in the stream may be more important than embryo survival in regulating fish abundance in many years. The abundance of juvenile salmon in pools of small rearing streams declines in nearly direct proportion to the amount of pool area or volume lost to fine sediment deposited in the pool. The number of juvenile salmon and trout a stream can support in winter is much reduced when the interstices in the stream substrate are filled with fine sediment.

In artificial stream channels, benthic insect density in fully sedimented riffles was one-half that in unsedimented riffles, but the abundance of drifting insects in the sedimented channels was not significantly less. In a natural stream riffle, benthic insects were 1.5 times more abundant in a plot cleaned of sediment, with mayflies and stoneflies 4 and 8 times more abundant, respectively.

Activity: clearing and tree harvest; dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Blahm, T.H. 1978. Toxicity of chemical fire retardants to juvenile coho salmon and rainbow trout. A dissertation. College of Forestry, Wildlife and Range Sciences, Univ. Idaho. 40 pp. (ADF&G, Habitat Library, B6196.)

Continuous flow bioassay tests demonstrated that commercial fire retardants were toxic to juvenile coho salmon, Oncorhynchus kisutch, and rainbow trout, Salmo gardneri. Ammonia present in the retardants caused the mortality. Statistical analysis indicated that increasing the diluent water pH from 7 to 8 increased the toxicity of the retardant to salmon and trout. The lethal concentrations that caused 50% mortality in 96 h with rainbow trout, (LC_{50}) for Phos-Chek XA were 224 ppm at pH 7 and 139 at pH 8. The LC_{50}s for Fire-Trol 931 were 1,238 ppm at pH 7 and 150 ppm at pH 8. An increase in test water temperature from 10 to 20°C did not cause statistically significant differences in toxic effect of the retardants. (Author's abstract)

Activity: chemical application.

Impact: change in levels of other toxic compounds.

Blanchard, M. 1981. Impact de la pollution par hydrocarbures sur une population de crustaces isopodes d'estran meuble intertidal. (Impact of hydrocarbon pollution on an intertidal isopod population.) In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4332.)

The effects of chronic oil pollution on an intertidal community of isopods Eusydice was conducted along the beach at Treompan, near the grounding point of the Amoco Cadez. Surveys were conducted monthly for 15 mo. A comparison was made between the population at the contaminated beach and a similar population at an uncontaminated site. Results of the study indicated that the population at the contaminated site had a lower density per square meter, and young organisms born during summer and winter 1978 exhibited an accelerated growth rate.

The authors speculated that the altered growth rates were the result of abundant food (plankton and organic deposits) resulting from the oil spill. (Author's abstract: modified)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Bodaly, R.A., and F.W. Lesack. 1984. Response of a boreal northern pike (*Esox lucius*) population to lake impoundment: Wupaw Bay, Southern Indian Lake, Manitoba. Can. J. Fish. Aquat. Sci. 41:706-714. (ADF&G, Habitat Library, #R2792.)

A population of northern pike was monitored for 1 yr prior to impoundment of the lake, which was increased in surface area by 9%, and for 5 yr after impoundment. Impoundment had a pronounced but transient effect on pike reproductive success. The abundance of young-of-the-year pike in 1977, the first year following impoundment, was 4-10 times higher than in the following 3 yr. Flooded terrestrial vegetation was apparently conducive to pike reproductive success only in the first year after inundation. A strong 1977 year class was evident in gill net catches 4 yr later. This year class was slower growing and in poorer condition than other year classes. The impoundment had no discernible effect on the growth, condition, or mortality of the adult pike population, with the exception of changes ascribed to the presence of the large 1977 year class. The growth of the adult pike population appeared to be limited by forage fish abundance, but variations in feeding on fish were largely unexplained and were probably due to natural variation. The year-to-year pattern of forage fish reproductive success could not be related to the timing of lake impoundment but may have been related to summer water temperatures. Variations in feeding on invertebrates appeared to be due to postimpoundment increases in productivity, but these changes were insufficient to affect population parameters. (Author's abstract: modified)

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in levels of nutrients.

Bodaly, R.A., R.E. Hecky, and R.J.P. Fudge. 1984a. Increases in fish mercury levels in lakes flooded by the Churchill River diversion, Northern Manitoba. Can. J. Fish. Aquat. Sci. 41:682-691. (ADF&G, Habitat Library, #R2798.)

Increases in fish muscle mercury levels, occurring coincidentally with flooding, are documented for three lakes for which pre- and postimpoundment data were available. Mercury levels in the muscle tissue of northern pike from a lake that was increased in surface area by 21% by flooding in 1976 increased from baseline values of 0.2-0.3 mg/g prior to flooding to 0.5-1.0 mg/g in 1978-1982. Muscle mercury levels of predatory species (esp. northern pike) from 10 lakes tested in three valleys were found near or exceeded the export marketing limit of 1.0 mg/g. Because mercury levels in fish from nearby unflooded lakes did not show increases, atmospheric fallout of the metal was not thought to be the cause of the increase. The authors found no industrial sources of mercury in the area and no agricultural activity. Mercury levels appeared to be related to the flooded terrestrial area compared with the preimpoundment lake area. They were highest (1.15-2.90 mg/g) in lakes that were increased in surface area by 282%, lower (0.60-1.53 mg/g) in lakes increased in surface area by 31-37%, and lowest (0.45-1.03 mg/g) in lakes increased in surface area by 13-21%. Fish muscle mercury levels responded quickly to impoundment, increasing noticeably within 2-3 yr. Declines in concentrations had not, in general, taken place within 5-8 yr of impoundment (with the exception of lake whitefish in one lake). The authors hypothesize that observed fish mercury level increases were due to the bacterial methylation of naturally occurring mercury found in flooded soils. (Author's abstract, modified.)

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; addition of physical barriers - diversions; change in levels of heavy metals.

Bodaly, R.A., T.W.D. Johnson, R.J.P. Fudge, and J.W. Clayton. 1984b. Collapse of the lake whitefish (Coregonus clupeaformis) fishery in Southern Indian Lake, Manitoba, following lake impoundment and river diversion. Can. J. Fish. Aquat. Sci. 41:692-700. (ADF&G, Habitat Library, #R2789.)

This paper discusses the collapse, both in poundage and market quality, of whitefish in Southern Indian Lake that followed lake impoundment and diversion of the Churchill River, in northern Manitoba, Canada. Evidence is presented that suggests that redistributions of whitefish stocks took place both within Southern Indian Lake and between adjoining water bodies, leading to the declines in catch and grade.

The majority of Churchill River water flow was diverted in 1974-1978 for hydroelectric purposes by a series of lake and river manipulations. Prior to diversion, the Churchill River entered Southern Indian Lake and exited at a falls. The level of Southern Indian Lake was raised 3 m above mean level by a control structure at the falls, and 80% of the flow began to be diverted through an artificial diversion channel into an adjoining river. The higher water level of Southern Indian Lake resulted in extensive and rapid wave erosion of surrounding clays, which are permafrost affected, in turn increasing the concentration of these fine-grained materials in lake waters and decreasing light penetration in most of the major lake basins.

The commercial fishery was substantial from the inception in 1941, with mean annual harvests of 333,500 kg over the three decades prior to lake impoundment. The whitefish catch prior to impoundment was composed almost exclusively (less than 99%) of light-colored, export (A) quality fish that were only lightly parasitized with the muscle cycst of Triaenophorus crassus, a cestode parasite. The market quality of the catch was maintained by selective fishing of certain lake basins and avoiding areas of the lake that were known to produce lower quality fish. Catch per unit of effort (CPUE) on traditional fishing grounds declined soon after impoundment to about one-half preflooding levels.

Total catches were maintained at or near preimpoundment levels by major increases in total effort until 1982, when the whitefish catch fell to about one-third of its preimpoundment mean. Fishermen also responded to declines in CPUE on traditional fishing grounds with a major geographic shift of effort into areas formerly avoided. As a result, darker colored, continental (B) quality whitefish comprised from 12 to 72% of the summer catch in the 4 yr following impoundment. Dark whitefish are less marketable due to color and higher rates of cestode infestation. Catch declines on traditional fishing grounds apparently reflect the emigration of fish to other Southern Indian Lake basins and/or to adjoining water bodies.

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; addition of physical barriers - diversions.

Bonsdorff, E. 1981. The Antonio Gramsci oil spill: impact on the littoral and benthic ecosystems. Mar. Pollut. Bull. 12:301-305. (ADF&G, Habitat Library, #R3862.)

The effects of a crude-oil spill in Sweden and Finland on the littoral communities were studied for 2 mo after the spill, and for the benthic community the long-term changes were recorded for 3 yr. The immediate effects were small in the uppermost littoral zone (the Cladophora belt), but in the lower littoral (the Fucus belt) severe effects were recorded. Meiofaunal densities decreased in crustacean and mollusc species but remained stable for the total community. Among the temporary meiofauna (juveniles of macrofauna) drastic changes were recorded between May and June. Amphipods (Gammarus spp., Pontoporeia affinis) and mysid shrimps (Mysis mixta) disappeared completely and for harpacticoid copepods and several mollusc species, considerable reductions in abundance were noted. Other groups such as polychaetes oligochaetes, turbellarians, and kinorynchs showed no detectable changes in abundance. The hatching of the next generation of crustaceans could have been severely affected. The population of the bivalue Macoma baltica declined after the spill, but long-term changes in the macrofaunal community could not be linked to the oil spill. Thus, the effects of the oil were rather small, although a large area was contaminated.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Borthwick, P.W., and J.M. Patrick, Jr. 1982. Use of aquatic toxicology and quantitative chemistry to estimate environmental deactivation of marine-grade creosote in seawater. Environ. Toxicology and Chem. 1:281-288. (ADF&G, Habitat Library, #R3875.)

The authors conducted laboratory experiments to a) determine the acute toxicity of marine-grade creosote to Eastern oysters, mysids (Mysidopsis bahia), pink shrimp, and fish (sheepshead minnow, Cyprinodon variegatus) and, b) define the biological and chemical half-life of creosote in sea water, using bioassays with the most sensitive species and quantitation with a gas chromatograph.

Results indicated that mysids were the most sensitive species tested. The acute toxicity of marine-grade creosote (expressed as 96-h LC_{50}) was 0.018 mg/l for mysids (in static water), 0.24 mg/l for pink shrimp (in flowing water), and 0.72 mg/l for sheepshead minnows (in static water). Shell deposition by Eastern oysters (in flowing water) was reduced by 50% at a creosote concentration of 0.71 mg/l. Sublethal effects in mysids were erratic swimming, loss of equilibrium, and lethargy preceeding death. Sheepshead minnows were immobilized, lost equilibrium, and displayed respiratory distress (reddened gills and flared opercula).

Mysid bioassays and chemical analyses estimated the half-life for marine-grade creosote in seawater was less than 1 wk. The authors comment that any extrapolation of these results to the natural environment should consider the following qualifications: 1) the penetration of sunlight into the carboys was not measured and may not be representative of the estuarine environment, 2) temperatures (as high as 96°C) that occurred in the glass carboys are not characteristic of most estuaries, and 3) the role of biodegradation, which may be an important factor affecting the fate of marine-grade creosote, was not determined.

Activity: filling (aquatic and wetland habitats).

Impact: change in levels of hydrocarbons.

Bottom, D.L., P.J. Howell, and J.D. Rodgers. 1985. The effects of stream alterations on salmon and trout habitat in Oregon. Oregon Department of Fish and Wildlife, Portland, OR. 70 pp. (ADF&G, Habitat Library, #B6039.)

This paper is a review of published and unpublished material concerning impacts of various human activities on salmonid habitat. Numerous papers are cited, augmented with comments and observations from the author that state that heavy silt loads in streams are detrimental to salmonid production. High turbidity is explained to have negative impacts on adult salmon migration, feeding, and spawning. Prolonged exposure to abrasive suspended sediment is stated to injure gill surfaces. Decreased permeability of spawning gravel is caused by cementation of sediments. Siltation also decreases pool size, reducing rearing and holding areas.

Farming is cited as a major contributor to siltation of streams. The fallow system of dry-land wheat farming exposes bare soil for extended periods and accelerates soil loss. Intense row crop production introduces warm, sediment- laden irrigation water into streams, which then are unsuitable for salmonid production.

Debris avalanches caused by logging can cause debris torrents, which are the rapid movement of water-charged soil, rock, and vegetation along stream channels. Common phenomena in the Pacific Northwest, the frequency and intensity of torrents increased with timber-harvest activities. Torrents often remove most of the structure, gravel, and vegetation in their path, and scour the stream channel to bedrock. Large amounts of debris are deposited as the torrent loses velocity in lower gradient reaches of a stream. Most torrents are confined to the upper reaches of streams. One instance is cited where a small debris torrent did not scout the main channel and improved fish habitat by delivering gravel and debris to a stream that lacked habitat structure.

Studies indicate that clear-cutting accelerates erosion by landslides two to four times the rate for forested lands. Road-related debris avalanches increased erosion from 50 to 340 times the rate in forested areas. Although roads accelerate erosion from landslides at a higher rate than clear-cutting, weighted by areas, clear-cutting and roads have been determined to contribute equally to total erosion from managed forests.

Numerous studies of small streams are cited that have shown significant decreases in trout production following stream channelization. Construction of revetments and channelization of large rivers influence the composition and diversity of fish communities. Channelization destroys the diversity of physical habitat necessary for optimum salmon production. Channelization creates a uniform depth and width profile and reduces water-storage capacity. Because of the increased hydraulic efficiency and gradient of a channelized stream, water velocities and erosive power are increased.

Splash dams, constructed to aid in moving logs downstream, have the same physical effect as debris torrents: the reduction of available rearing habitat for juvenile and resident salmonids.

Activity: channelizing waterways; clearing and tree harvest; filling (aquatic and wetland habitats); grading/plowing; water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Boucher, G. 1985. Long term monitoring of meiofauna densities after the Amoco Cadiz oil spill. Mar. Pollut. Bull. 16(8): 328-333. (ADF&G, Habitat Library, #R4338.)

Long-term temporal variations in nematode and copepod densities were monitored in the upper and lower part of the Bay of Morlaix (West Channel), which was heavily contaminated by the 1978 Amoco Cadiz oil spill. Deseasonalization of abundance data allowed estimates to be made of different components, namely the annual and seasonal trends and residue. Reduced nematode abundance was long-lasting in both types of sediment investigated:it appeared to be a gradual decrease in sublittoral sand, but there was a dramatic reduction in estuarine mud 2 yr after disturbance. Copepod variability, however, was related to seasonal factors. The most obvious effect of pollution was the total mortality of Ampeliscidae and the succession of macrofauna species, characterized by a shift from surface suspension and deposit feeders as a whole (amphipods) to deposit feeders only (polychaetes followed by bivalves). However, less obvious changes resulted in a decrease of the chlorophyll a/pheophytin a ratio, which suggests a depletion in primary production. (Author's abstract and parts of discussion)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Bourne, N., H. Rogers, H. Mahood, and D. Neil. 1981. Water quality study of Ladysmith Harbour, British Columbia. Can. Tech. Rept. of Fish. and Aquat. Sci., No. 1026. 57 pp. (ADF&G, Habitat Library, #B6101.)

A bioassay using Pacific oyster (Crassostrea gigas Thunberg) embryos was done on surface waters collected from a depth of 0.5 m at five locations from the mouth to the head of Ladysmith Harbour, British Columbia, from January 8 to September 17, 1979. Water quality as determined by the bioassay was poorer in Ladysmith Harbour water than in control water at the Pacific Biological Station in Naniamo. There was a gradient in water quality in the harbour from the mouth, where it was best, to the head, where it was poorest, but local exceptions to this trend were evident. Water samples were collected in 1979 and 1980 and analysed by gas chromatograph-mass spectrometry to identify the possible causes of the poor water quality. No definitive cause was identified, but wood extractives, chlorophenols, fuel additives, and dimethyl sulphide, all of which can be toxic to oyster larvae, were found. Six samples of water were collected from June 26 to September 13, 1979, and analysed for copper, mercury, and arsenic content, but concentrations of these metals were too low to explain the poor water quality. (Authors' abstract)

Activity: processing oil/gas; transport of oil/gas/water - water; transport personnel/equipment/material - water.

Impact: change in levels of other toxic compounds - other; change in levels of hydrocarbons.

Boussu, M.F. 1954. Relationship between trout populations and cover on a small stream. J. Wildl. Manage. 18(2):229-239. (ADF&G, Habitat Library, #R5092.)

A study was made of the relationship of eastern brook trout, rainbow trout, and brown trout populations to cover in Trout Creek, Gallatin County, Montana. Fourteen sections were established as study areas. These sections were selected on the basis of presence or absence of cover features such as overhanging brush and undercut banks. Fish were collected by shocking and arbitrarily classified into three length groups: legal fish, sublegal fish, and fingerlings. All sections were inventoried four times prior to alteration (July, December, 1951; March, July, 1952). Cover on eight sections was altered. Five sections were unaltered and used as controls. One section was used for general observations. All sections were inventoried three times following alteration (September, December, 1952; March, 1953). A comparison of prealteration and postalteration populations was made. A total of 155 ft^2 of brush cover was applied to four sections. The increase in total pounds following this application averaged 1.60 per inventory. The populations in three control sections increased by an averge of 0.23 lb per inventory. A total of 128 ft^2 of natural brush cover was removed from two sections. The decrease in total pounds of fish per inventory following this removal was 1.71. A control section increased in total pounds by an average of 0.18 per inventory. Fifteen square feet of undercut bank was removed from two sections. The decrease in total pounds per inventory following this removal was 0.25. The control section increased in total lbs an average of 0.28 per inventory. Aquatic vegetation appeared to be of value as cover when rooted to the stream bottom and also while free-floating. (Author's summary)

Activity: channelizing waterways.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Bowden, C.F., M.M. McGuiness, and R.C. McKean. 1983. Fishery productivity and instream mining: implication for the Bristol Bay region. Unpubl. ADF&G, Bristol Bay Study Group, Anchorage. 46 pp. (ADF&G, Habitat Library, #R2944.)

This paper discusses several instances in the literature where sport and commercial fisheries have been negatively effected by turbidity generated from placer mining operations and proceeds through a detailed presentation of potential turbidity/sedimentation-induced deleterious effects to salmonids at various life stages. This paper further encapsulates available information of an economic nature comparing commercial and sportfishing income versus that of placer mining in the Bristol Bay, Alaska, region.

Activity: dredging; processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

Bradt, P.T., and G.E. Wieland III. 1978. The impact of stream reconstruction and a gabion installation on the biology and chemistry of a trout stream. (ADF&G, Habitat Library, #B1838.)

The effect of the rechanneling of the stream and the adjacent road building was to leave a stream wider and shallower than it had been originally, with bare banks, no canopy cover, and a uniform substrate. This rechanneled stream was open to intense solar heating in summer due to the lack of shade and the shallow depth of the stream.

Reconstruction efforts to correct the above deficiencies included 1) the placement of large rocks and small dams to create pool and riffle areas; 2) the placement of gabions to narrow and deepend the stream channel; and 3) planting of ground cover, shrubs, and tress along the bank to give shade (as the trees grew) and prevent further erosion.

As the stream passes through the gabion installation the following chemical and physical parameters increase: conductivity, dissolved oxygen, percent oxygen saturation, pH, and alkalinity. Orthophosphate concentrations decreased downstream. Physical parameters that increased through the study area are flow velocity and discharge. Biological parameters that increased from station 1 to station 5 are total number of macroinvertebrates, total number of taxa, and biomass of macroinvertebrates. (Author's conclusions: partial)

Activity: channelizing waterways; grading/plowing.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - diversions; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness; change in levels of nutrients.

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 12. New Westminister, B.C., Canada. 26 pp. (ADF&G, Habitat Library, #B6180.)

Although this report does not pertain to a specific developmental activity, it clearly documents the influence of water velocity, daylight and dissolved oxygen levels on development and weight of sockeye salmon enbryos and alevins. As such, it provides specific documentation that directly supports several other literature sources involving these variables.

The effects of water velocity, daylight and dissolved oxygen on the development and weights of sockeye salmon embryos and alevins were investigated. Before hatching, embryos were unaffected by the range of velocities studied but were affected by exposure to diffuse daylight and different levels of dissolved oxygen. After hatching, the weights of the alevins and their rates of weight gain were influenced by velocity and oxygen, and their mortality was influenced by high velocities, especially when exposed to diffuse daylight. The significance of the effects of the three factors on the ultimate survival of fry are discussed. (Author's abstract: modified)

Activity: clearing and tree harvest; grading/plowing; processing minerals; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in level of dissolved oxygen, nitrogen.

Brannon, J.M. 1978. Evaluation of dredged material pollution potential. U.S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi. Tech. Rept. DS-78-6. 39 pp. (ADF&G, Habitat Library, #B5314.)

Results from Brannon's evaluation indicate that the short-term impacts of dredging and aquatic disposal on water column organisms are minimal. However, dredged material disposal may have an adverse impact on benthic and epibenthic organisms at the disposal site. Limited toxicity occurs only during worst-case experimental situations that do not exist in the field. Most dredged material has not proven very toxic to benthic and epibenthic organisms. Some dredged material can be extremely toxic and bioassay procedures are available to identify these toxic sediments. Brannon concludes that the long-term sublethal effects of dredged material disposal on species diversity and density at field sites are not well known and are subject to more study.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of chlorinated compounds; change in levels of biocides.

Brazier, J.R., and G.W. Brown. 1973. Buffer strips for stream temperature control. Forest Research Laboratory, Oregon State Univ., Corvallis. Research Paper 15. 8 pp. (ADF&G, Habitat Library, #R2290.)

During clear-cut logging, complete removal of the forest canopy and the shade it provides to small streams can cause large increases in water temperature. Such increases in temperature can be prevented if buffer strips of vegetation are left along the stream to provide shade. The purposes of this paper are to define the characteristics of buffer strips that are important in regulating the temperature of small streams and to describe a method of designing buffer strips that will ensure no change in stream temperature as a result of logging and at the same time minimize the amount of commercial timber left in the strip.

Commercial timber volume alone is not an important criterion for temperature control. Further, the width of the buffer strip is also not an important criterion. For the small streams studied as part of this research, the maximum shading ability of the average buffer strip was reached within a width of 80 ft. Specifying standard 100-200-ft buffer strips for all streams generally will include more timber than necessary. (Note that these distances pertain only to stream shading and do not consider other factors, such as sedimentation. The canopy density along the path of incoming solar radiation best describes the ability of the buffer strip to control stream temperature. An estimate of this value can be obtained easily by foresters laying out buffer strips in the field and will ensure proper design of the buffer strip for control of stream temperature. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature.

Brett, J.R., W.C. Clarke, and J.E. Shelbourn. 1982. Experiments on thermal requirements for growth and food conversion efficiency of juvenile chinook salmon, Oncorhynchus tshawytscha. Can. Tech. Rept. Fish. Aquat. Sci. No. 1127. 29 pp. (ADF&G, Habitat Library, #B1223.)

Feeding and growth experiments on Nechako River and Big Qualicum River chinook juveniles were conducted for 28 d at temperatures from 16 to 24°C (Nechako) and 14 to 25°C (Big Qualicum). On maximum daily ration, optimum temperature for growth was approximately 19°C, above which feeding and growth decreased, particularly above 22°C. Mortalities reached 64% at 25°C, in agreement with earlier studies on lethal temperatures. In comparison with Qualicum chinooks, Nechako juveniles had a lower growth rate and food conversion efficiency at all but the highest temperatures.

Measures of the growth rate of natural populations in the Nechako River showed that the rate corresponded to a feeding level of 60% of maximum daily intake. The effect of such reduced ration on the optimum temperature for growth was deduced from a response model for sockeye salmon. This showed that the expected optimum in nature for growht of Nechako River chinooks would occur at 14.8°C. It was further deduced that sublethal growth stress (20% reduction in growth from optimum) would occur in the region of 18-19°C and that for this feeding level no growth would be possible at 21.4°C. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing; water regulation/withdrawal/irrigation.

Impact: change in water temperature.

Brickell, D.C., and J.J. Goering. 1971. Chemical effects of decomposing salmon carcasses of aquatic ecosystems. Pages 183-206 in Oceanography of the Bering Sea. Phase I: Turbulent upwelling and biological productivity mechanisms in the southeastern Bering Sea and Aleutian Islands. Univ. Alaska, Inst. Mar. Sci. Rept. No. R-71-9. 212 pp. (ADF&G, Habitat Library, #R3254.)

The nitrogen dynamics of a bay receiving seafood processing wastes (Iliuliuk Bay on Unalaska Island) is compared to the dynamics of a natural estuary receiving hundreds of salmon carcasses at the end of the spawning season (Baranof Island in Southeast Alaska). In Iliuliuk Bay, a drastic increase in the concentration of NH4+N, and a depletion in oxygen was noted in the water column. The most significant increase in ammonium and decrease in oxygen occurred at depths between 15 and 25 m. A seaward decreasing NH4+N content suggested that NH4+N originating in the bay had an important influence of the nitrogen economy of the surrounding ocean.

Studies in the natural system on Baranof Island revealed concentrations of ammonium and organic nitrogen that, though measured in a different way, were approximately the same as in Iliuliuk Bay. Thus, high ammonium and organic nitrogen concentrations can also occur in the natural environment.

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of nutrients.

Brodersen, C.C., S.D. Rice, J.W. Short, T.A. Mecklenburg, and J.F. Karinen. 1977. Sensitivity of larval and adult Alaskan shrimp and crabs to acute exposures of the water-soluble fraction of Cook Inlet crude oil. Pages 575-578 in Proceedings 1977 oil spill conference (prevention, behavior, control, cleanup). American Petroleum Institute, Washington, D.C. (ADF&G, Habitat Library, #R3685.)

The sensitivity of adult and larval Alaskan shrimp and crabs to the water-soluble fraction (WSF) of Cook Inlet crude oil was measured by tests using 96-h static tests at the water temperatures that these animals noramlly encounter. Larval crustaceans were found to die more slowly than adults, making it necessary to measure sensitivity in terms of concentrations causing moribundity (the cessation of all motion and reaction). The cessation of all motion and reaction indicated moribundity in adults, and the cessation of swimming indicated moribundity in larvae exposed for 96 h. The 96-h LC_{50} for moribundity for Stage I larvae ranged from 0.95 to 1.8 ppm, depending on species, whereas 96-h LC_{50} for adults ranged from 1.9 to 4.2 ppm oil. Sensitivities for Stages I-VI larvae of coonstripe shrimp ranged between 0.24 and 1.9 ppm.

Larvae were more sensitive to oil than adults. The sensitivity of larvae depended on the species and developmental stage. Larvae are probably more vulnerable than adults to oil exposure because of greater sensitivity to oil and greater susceptibility to predation. Coldwater species may be particularly vulnerable because of increased time spent as developing larvae. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Brooks, A.S., and G.L. Seegert. 1975. The toxicity of chlorine to freshwater organisms under varying environmental conditions. Chapter 14 in R.L. Jolley, ed. Water chlorination, environmental impact and health effects Vol. 1. Proceedings of the conference on the environmental impact of water chlorination, Oak Ridge, TN, Oct. 22-24. 1975. Ann Arbor, Michigan: Arbor Science Publishers. (ADF&G, Habitat Library, #R3972.)

This paper reviews studies which have been conducted under a myriad of environmental conditions in attempts to quantify the toxicity of chlorine to freshwater organisms. Included in the review are experiments run in relatively clean waters and sewage effluents. Studies are also included that involved continuous and intermittent chlorine applications and tests conducted under a wide range of temperatures. Data from these studies are reviewed in light of the conditions under which the tests were conducted. A synthesized view is presented of the toxicity of chlorine to freshwater biota in terms of the level and duration of exposure, temperature, and the chemical nature of the water in which the experiments were conducted. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Brown, E.J., H.V. Luong, and J.M. Forshang. 1982. The occurrence of Thiobacillus ferrooxidans and arsenic in subarctic streams affected by gold mine drainage. Arctic 35(3): 417-421. (ADF&G, Habitat Library, #R2943.)

Thirty-five streams in gold-mining regions between Rampart, Alaska, and Dawson City, Yukon Territory, were sampled to determine dissolved arsenic concentrations, and numbers of the acidophilic iron- and sulfur-oxidizing bacterium Thiobacillus ferrooxidans. The pH of the streams varied from 6.3 to 8.6, and the streams were nearly saturated with dissolved oxygen. T. ferrooxidans was found in 8 of 9 streams affected by gold-mine drainage and in only 1 of 26 streams not affected by gold-mine drainage. Dissolved arsenic in amounts less than 50 ppb (the Environmental Protection Agency's recommended drinkable water standard limit) was found only in streams near Fairbanks, Alaska, whether gold mining was occurring or not. High levels of arsenic in streams and mining activity on those streams are not directly related. (Authors abstract: modified)

Activity: dredging; processing minerals.

Impact: change in levels of heavy metals.

Brown, G.W. 1972. Logging and water quality in the Pacific Northwest. Pages 330-334 in S.C. Csallany, T.G. McLaughlin, and W.D. Striffler, eds. American water resources association symposium 1972, Urbana, IL. (ADF&G, Habitat Library, #R2299.)

The author presents a comprehensive review of how logging and associated activities impact sediments, nutrients, water temperature, and dissolved oxygen. He also discusses the control of water quality and enforcement of standards on small forest streams.

In Oregon, approximately 536 b board feet of standing sawtimber annually supply 9.1 b board feet of national and international markets. In the past, management of the area's forested watersheds has focused primarily upon the production of timber. Many of the streams in these watersheds are also the spawning and rearing sites for anadromous fishes and, in many instances, the source of water for Northwest municipalities. Management of these watersheds is indeed in a state of transition. Recent research has shown that clear-cut logging can significantly affect stream temperature and concentrations of sediment and dissolved oxygen.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; change in level of dissolved oxygen, nitrogen; change in levels of nutrients.

Brown, G.W., and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resour. Res. 6(4):1133-1139. (ADF&G, Habitat Library, #R2289.)

The principal source of energy for warming streams is the sun. The amount of sunlight reaching the stream may be increased after clear-cut logging. Average monthly maximum temperatures increased by 14°F, and annual maximum temperatures increased from 57 to 85°F 1 yr after clear-cut logging on a small watershed in Oregon's coast range. In a nearby watershed where strips of brush and trees separated logging units from the stream, no changes in temperature were observed that could be attributed to clear-cutting. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; alteration of natural cover - riparian vegetation.

Brown, G.W., and J.T. Krygier. 1971. Clear-cut logging and sediment production in the Oregon Coast Range. Water Resour. Res. (7)5:1189-1198. (ADF&G, Habitat Library, #R2138.)

The impact of road construction, two patterns of clear-cut logging, and controlled slash burning on the suspended sediment yield and concentration from three small watersheds in the Oregon Coast Range was studied for 11 yr. Sediment production was doubled after road construction but before logging in one watershed and was tripled after burning and clear-cutting of another watershed. Felling and yarding did not produce statistically significant changes in sediment concentration. Variation in the relation between sediment concentration and water discharge on small undisturbed streams was large. Conclusions about the significance of all but very large changes in sediment concentration are limited because of annual variation for a given watershed, variation between watersheds, and variation with stage at a given point. (Author's abstract)

Activity: burning; clearing and tree harvest; grading/plowing.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Brown, G.W., A.R. Gahler, and R.B. Marston. 1973. Nutrient losses after clear-cut logging and slash burning in the Oregon Coast Range. Water Resour. Res. 9(5):1450-1453. (ADF&G, Habitat Library, #R3832.)

Nutrient release from three small watersheds in Oregon's Coast Range was monitored for 2 yr before and 2 yr after logging. One watershed served as an untreated control. No change in the concentration or yield of nitrate nitrogen, phosphorus, or potassium was observed after patch-cut logging of a 303.3 ha area. In an area of 70.7 ha that was clear-cut and burned, maximum nitrate nitrogen concentrations increased from 0.70 to 2.10 mg/l. Nitrate nitrogen concentrations returned to prelogging levels by the sixth year after logging. Yield of nitrate nitrogen increased from 4.94 to 15.66 kg/ha the first year after treatment. Potassium concentrations increased markedly after burning from about 0.60 to 4.40 mg/l but returned to prelogging levels within 2 mo. Phosphorus concentrations were unchanged.

Complete forest removal followed by slash burning can temporarily but significantly alter the pattern of nutrient loss in forests of the Oregon Coast Range. Under the soil and revegetation conditions observed in this study, such changes will not degrade water quality with respect to nutrients or significantly reduce the productivity of forest soils. Partial clear-cutting or patch-cutting under these soil and vegetation conditions produces no significant change. (Author's abstract and conclusion: modified)

Activity: burning; clearing and tree harvest.

Impact: change in levels of nutrients.

Brown, R.J., and W.D. Baker. 1975. Mining, as it affects aquatic resources. in: Pages 97-107 in R.V. Corning, R.F. Raleigh, G.D. Schuder, Sr., and A. Wood, eds., Proceedings, symposium on stream channel modification. Harrisonburg, VA. (ADF&G, Habitat Library, #R3817.)

This paper is a review of literature dealing with mining and gravel dredge operations that alter stream channels. Papers are cited where work has been performed in several states of the northwest United States, but the author cites primarily projects conducted in North Carolina. Irrespective of where channel alteration is conducted, the principles of hydrology are similar.

Gravel used for construction purposes is commonly dredged from stream beds. An instance of severe consequences caused by in-stream dredging is cited where overall down-cutting of the upstream channel followed gravel removal, which threatened to undermine several bridge piers. Stream banks are also susceptible to increased erosion.

Channelization of a Tennessee creek is cited as the cause of the elimination of fish species (darter and sculpin) that occupy riffles as primary habitat. Among game fish greater than 6 in (153 mm) in length, one study found no significant return toward the predredging populations after 40 yr following alteration of the channel. One study determined that the carrying capacity of game fish in nondredged streams is 400% higher than that of streams channelized by dredging.

The dredging of gravel riffles removes the most productive areas of a stream and creates a pool that is relatively unproductive and has an unstable sand bottom. An Idaho study found that mining for 52 d increased the mean depth of silt in the stream bed from 55 ml to 273 ml. This increase is considered a minimum, because the sample-collecting devices used in that study were overwhelmed with silt.

The invertebrate order Ephemeroptera has been found sensitive to gravel mining by one paper cited. Several Dipteran families were found intermediate to very tolerant to this activity. Several papers found severe reductions of benthic macroinvertebrates. Drift organisms (the downstream displacement of aquatic insects) were found to increase from 115 to 652 lb/d in a dredged stream.

Reference is made to mining on either or both sides of a stream, resulting in a "perched stream" that tends to overflow the dikes created and result in flooding.

Activity: channelizing waterways; dredging; processing minerals.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; introduction or removal of species.

Brown, V.M., D.H.M. Jordan, and B.A. Tiller. 1969. The acute toxicity to rainbow trout of fluctuating concentrations and mixtures of ammonia, phenol, and zinc. J. Fish Biol. 1:1-9. (ADF&G, Habitat Library, #R3881.)

The authors utilize a previously determined method to measure the effect of a mixture of similar poisons in water by summation of their individual toxic fractions. The research reported in this paper describes the effects of (a) fluctuation concentrations of poisons and (b) mixtures of ammonia, phenol, and zinc.

All experiments were made with hatchery-reared rainbow trout in aquaria containing 40 l of solution. The first series of tests on the toxicity of fluctuating concentrations of zinc and ammonia was made at 10 to 12°C, with rainbow trout of 8.5 to 14.5 cm FL. When zinc and ammonia were tested together, it was arranged that each poison contributed equally to the toxicity of the mixture. In the second series of experiments, with mixtures of three poisons maintained at constant concentrations, rainbow trout of 5 to 9 cm FL were used. Tests were carried out at an average temperature of 12°C and an average pH value of 7.8.

The results showed that 48-h LC_{50} concentrations of ammonia, zinc, and ammonia plus zinc were similar whether trout were immersed in constant concentrations of poisons or in concentrations fluctuating within $\pm$ 50% of the 48-h LC_{50} at equal intervals of time, as long as the periodicity of the fluctuations did not exceed the resistance time for the particular poison involved. The experiments also showed that except when zinc predominated in a mixture, the fractional toxicities of the three poisons tested here could be summed to give the toxicity of the mixture. The 95% confidence intervals effectively embraced the value of 1.0. When zinc predominated (greater than 70%) in the mixture, some possibly antagonistic effect appeared to be demonstrated.

The authors determined 48-h LC_{50} values for phenol, ammonia, and zinc for rainbow trout (5 to 9 cm FL) in 12°C (average temperature) and 7.8 pH (average water). These values were 1) ammonia 48-h LC_{50} = 35.0 mg/l, 95% confidence limits = 30.2 to 40.6 mg/l; 2) phenol 48-h LC_{50} = 4.0 mg/l, 95% confidence limits = 3.50 to 4.50 mg/l.

The authors relate their observed results (using the summation method of 48-h LC_{50}) to those results obtained by other researchers and by using standard methods. They noted that large differences occurred between the described methods.

Activity: filling (aquatic and wetland habitats); processing minerals; processing oil/gas; sewage disposal; transport of oil/gas/water - water.

Impact: change in levels of heavy metals; change in levels of hydrocarbons.

Brusven, M.A., and K.V. Prather. 1974. Influence of stream sediments on distribution of macrobenthos. J. Entomol. Soc. B. C. 71:25-32. (ADF&G, Habitat Library, #R2935.)

Studies were conducted in the laboratory and field to determine the substrate relationships of five species of stream insects representing the orders Ephemeroptera, Plecoptera, Trichoptera, and Diptera. Various combinations of pebble and sand were tested in the presence or absence of cobbles. Substrates with cobble were generally preferred over substrates without cobble. The preference for cobble generally increased as the sediments around the cobble decreased in size. Substrates with unembedded cobble were slightly preferred over half-embedded cobble; completely embedded cobble and fine sand proved unacceptable to most species. Three types of substrate-distribution patterns are recognized: stream insects that inhabit substrate surfaces, interstices, and both substrate and interstices.

Activity: clearing and tree harvest; dredging; grading/plowing.

Impact: addition of substrate materials.

Bryan, G.W. and P.E. Gibbs. 1983. Heavy metals in the Fal Estuary, Cornwall: a study of long-term contamination by mining waste and its effects on estaurine organisms. Marine Biol. Ass. U.K. Occasional Pub. No. 2. Deven, England. 112 pp. (ADF&G, Habitat Library, #B1214.)

The Fal estuary system has received inputs of heavy metals from mining activities over many centuries. The waters contain high concentrations of zinc, iron, magnesium, copper, arsenic, and cadmuim. The sediments are highly contaminated and contain levels of copper, zinc, arsenic, and tin from 1,500 to 3,500 ug/g. Comparison of the fauna with that of similar areas shows that the Fal system supports a sparse fauna. Bivalve larvae and junveniles are unable to withstand the toxic conditions. However, some species have developed copper or zinc tolerant strains which have established breeding populations within the system. Tolerant species often contain high concentrations of metals, particularly copper. Some of these species form the major food of predators such as fish and birds, which thereby have high metal intakes. (Author's abstract: modified)

Activity: dredging; grading/plowing; processing minerals.

Impact: change in levels of heavy metals.

Bryant, M.D. 1980. Evolution of large, organic debris after timber harvest: Maybeso Creek, 1949-1978. USDA: Forest Service Gen. Tech. Rept. DNW-161. Pacific Northwest Forest and Range Experiment Station. Juneau, AK. (ADF&G, Habitat Library, #B0327.)

Timber harvest has caused extensive changes in the stream channel of Maybeso Creek, Southeast Alaska. Some of these changes may have been imposed by equipment operating in the stream, but most were related to accumulations of large debris. Natural accumulations appeared stable compared with those created by logging debris. Throughout logging, natural accumulations collected large amounts of logging debris and subsequently washed out.

The absence of old-growth forest along the streambank effectively eliminated new accumulations. The decrease in the number of accumulations of large debris after logging was apparent. As these accumulations are dissipated, pools formed around accumulations of large debris will be replaced by riffles; thus, there will be a net increase in riffle areas. As these areas stabilize, the stream channel morphology will be determined by rock formations and streambank.

It was evident that large quantities of tree-size material had been assimilated between 1960 and 1978, either within the stream or along the banks. Although the amount of debris throughout the active channel has decreased, debris along the bank and projecting into the channel still plays a role in channel morphometry. In some cases, it will contribute to bank stability. These areas will also contribute to the formation of pool areas important to juvenile salmonids.

The observations of events following logging on Maybeso Creek show that accumulations of large natural debris play an active role in channel morphometry and form relatively stable features, such as pools and side channels. Natural debris accumulations are most severely affected by large floatable logging debris, whereas bedrock areas are generally unaffected. (Author's conclusions)

Activity: clearing and tree harvest.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Bryant, M.D. 1981. Evaluation of small diameter baffled culvert for passing juvenile salmonids. USDA: Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-384, Juneau, AK. (ADF&G, Habitat Library, #B3668.)

A 36-in diameter, 30-ft-long culvert with off-set baffles was set at a 10% gradient in an artificial stream channel on Admiralty Island, Alaska. Juvenile coho salmon (Oncorhynchus kisutch), Dolly Varden char (Salvelinus malma), and cutthroat trout (Salmo clarki), all less than 120 mm fork length and taken from nearby streams, were able to move up the culvert. Within the range of discharges most commonly examined (10 liters/sec and 16 liters/sec, or 0.4 cubic ft/sec and 0.6 cubic ft/sec, respectively), discharge did not appear to affect fish movement up the culvert. Below 5.23 liters/sec (0.2 cubic ft/sec), however, water in the culvert was too shallow for the baffles to operate. At a discharge greater than 17 liters/sec (equal to 0.65 cubic ft/sec) - approximately 14 cm of water depth in the culvert - no fish moved up the culvert; but in these tests such a discharge occurred only once. Additional tests are required to more precisely define an upper discharge limit, but it appears that discharges of more than 5 cm of water over the top of the baffles will act as a velocity barrier.

The factors that limit fish passage during a given time period are the maximum water velocity through the culvert and the darting speed of the fish. Because darting speed is frequently three to four times greater than sustained swimming speed, velocities that might block fish swimming at a sustained speed may be tolerated in a baffled culvert.

Two potential problems with baffled culverts may occur at the outlet: 1) velocities and 2) scour of stream bottom. Both can be avoided by proper design. Within the discharge ranges that were examined, a baffled section at the lip of the culvert disrupted the outlet velocity enough to allow passage of small juvenile salmonids. When coho salmon (average fork length 49 mm) were tested at water discharges below 14 liters/sec (0.5 cubic ft/sec) none passed up the culvert until a baffle was placed at the lip of the culvert outlet. If hydraulic energy is not dissipated at the outfall, the streambed will scour, resulting in a drop-off at the outfall that will effectively block upstream passage.

Activity: stream crossing - structures.

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Bryant, M.D. 1983. The role and management of woody debris in west coast salmonid nursery streams. N. Am. J. Fish. Manage. (3):322-330. (ADF&G, Habitat Library, #R3602.)

Debris removal is a frequently used management technique for small streams in logged watersheds, but many stream-cleaning techniques overlook important habitat requirements of juvenile salmonids. Reviews of some past management practices show little systematic evaluation or monitoring of physical or biological effects. A review of several studies (most of them not associated with debris removal) shows the importance of woody debris as salmonid habitat. The role of organic debris in small stream systems is discussed, and a set of criteria for debris removal is proposed. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation.

Buchanan, D.V., R.E. Millemann, and N.E. Stewart. 1970. Effects of the insecticide Sevin on various stages of the Dungeness crab, Cancer magister. J. Fish. Res. Bd. Can. 27:93-104. (ADF&G, Habitat Library, #R3861.)

During the life history of the Dungeness crab, Cancer magister, crabs in the early larval stage are more sensitive to Sevin than are juveniles and adults. A concentration of 1.0 mg/l did not affect egg hatching but prevented molting of all prezoeae to zoeae. The concentration that killed 50% of the first-stage zoeae during a 96-h exposure (96-h EC50 for death) was estimated to be 0.01 mg/l. Few zoeae were killed in 24 h by 82.0 mg/l, but the 24-h EC50 for death within 15 d after the exposure was estimated to be 0.015 mg/liter. Survival of zoeae after 25 d exposure to concentrations of 0.0001, 0.00032, 0.001, 0.0032, and 0.01 mg/l were 83, 60, 69, 21, 0%, respectively, and control survival was 79%. Molting was delayed at a concentration as low as 0.0001 mg/liter.

Young juvenile crabs are more sensitive to Sevin than are older juveniles or adults. The 24-h EC50s for death or irreversible paralysis were estimated to be 0.076 and 0.35 to 0.62 mg/l for second- and ninth-stage juveniles, respectively. The behavior, growth, and survival of juvenile crabs were not affected when the animals were exposed to 0.032 mg/l of Sevin for 24 h and then held in clean sea water for 44 d. The 24-h and 96-h EC50s for death or irreversible paralysis were 0.49 and 0.26 mg/l, respectively, for adult crabs. After eating cockle clams that had just been exposed for 24 h to 1.0, 3.2, and 10.0 mg/l of Sevin, 22, 77, and 100% of adult crabs, respectively, were irreversibly paralyzed within 6 h. The significance of these findings in field application of Sevin to control oyster pests and predators is discussed.

Activity: chemical application.

Impact: change in levels of biocides.

Buchanan, D.V., P.S. Tate, and J.R. Moring. 1976. Acute toxicities of spruce and hemlock bark extracts to some estuarine organisms in Southeastern Alaska. J. Fish. Res. Bd. Can. 33:1188-1192. (ADF&G, Habitat Library, #R3025.)

In a laboratory, Sitka spruce bark extracts were found to be toxic to adult and larval pink shrimp and larval Dungeness crab. Sitka spruce and western hemlock bark extracts were found to be toxic to pink salmon fry. For salmon fry, toxic effects were observed as soon as 3 h after exposure to hemlock bark extracts. After a 96-h exposure, 50% of the test fry were killed at a concentration of 56 mg/l. With a 96-h exposure of spruce extracts, 50% of the fry were killed at concentrations of 100-120 mg/l.

Spruce bark extracts were consistently toxic to all invertebrates tested. Fifty percent mortality over a 96-h period for each species was reached at 415, 205, and 530 mg/l for larval shrimp adult shrimp and larval crabs, respectively. Using loss of swimming as the criterion, 50% incapacity was reached at 155 mg/l for larval shrimp, and 225 mg/l for larval crabs. Spruce bark pulp was found to be 2 to 6 times more toxic than extracts to shrimp larvae. (Author's abstract: modified)

Activity: chemical application.

Impact: change in levels of biocides.

Bulkley, R.V. 1976. A study of the effects of stream channelization and bank stabilization on warm water sport fish in Iowa: subproject 1 inventory of major stream alterations in Iowa. USDI: USFWS. FWS/OBS-76-11. 338 pp. (ADF&G, Habitat Library, #B6313.)

Aerial photographs and public records were used to determine the amount of channelization of Iowa streams with drainage areas greater than 50 mi^2. The extent of channelization was determined by measuring stream sinuosity. It is estimated that from 1,000 to 3,000 mi of streams have been lost in Iowa since settlers first arrived. (Author's abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; alteration of natural cover - overhanging bank or shoreline.

Bulkley, R.V., R.W. Bachmann, K.D. Carlander, H.L. Fierstine, L.R. King, B.W. Menzel, A.L. Witten, and D.W. Zimmer. 1976. Warmwater stream alteration in Iowa: Extent, effects on habitat, fish, and fish food, nd evaluation of stream emprovement structures (summary report). Iowa Cooperative Fishery Research Unit, Iowa State Univ. USFWS, Biological Services Program FWS/OBS-76-16. (ADF&G, Habitat Library, #B0990.)

Studies were conducted from 1973 to 1976 to determine the extent of stream channelization in Iowa and to evaluate the differences in populations of fish and fish-food organisms in channelized and unchannelized streams, effects of stream altercations for highway bridge construction, and the value of stream bank stabilization structures to fish habitat.

Channelization resulted in more uniform water depth and current velocity in the streamm with a reduction in habitat diversity. Sinuous streams had greater concentrations of drift organisms than did straightened channels. More species of fish were found in natural sections, although fish were as abundant in short-reach sections (0.5 km) that were channelized 10 to 15 yr ago as in natural sections wherever brush piles and trees had accumulated in the stream. The study concluded that no long-reach (1.0 km) channelization should be conducted and that the effects of short-reach projects can be lessened by leaving as much meander in the stream as possible and by proper placing and design of bank-stabilization structures. (Author's abstract: modified)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Burks, S.A., and R.M. Engler. 1978. Water quality impacts of aquatic dredged material disposal (laboratory investigations). U.S. Army Engineers Waters Experiment Station, Vicksburg, Mississippi. Tech. Rept. DS-78-4. 35 pp. (ADF&G, Habitat Library, #B5315.)

Burks and Engler report that open-water disposal of dredged material can have a temporary impact if the dredged sediments contain high levels of chlorinated pesticides, PCBs, or ammonia. Harmful levels of heavy metals can be released from sediments but probably would not be released by most typical dredging or disposal operations. Chlorinated hydrocarbon pesticides, PCBs, oil and grease compounds, heavy metals, and phosphates are rapidly absorbed by suspended particulate matter in the water column and may resediment in quiet areas.

Resedimentation of suspended particles that have absorbed any of these contaminants may impact benthic organisms. Detritus-feeding organisms may ingest the contaminants and introduce them into the food chain. The authors note that the effects from open-water disposal of dredged material may last more than a year but cannot be predicted at this time.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of chlorinated compounds; change in levels of biocides; change in levels of other toxic compounds - other; change in levels of hydrocarbons; change in levels of nutrients.

Burns, J.W. 1970. Spawning bed sedimentation studies in northern California streams. Calif. Fish Game 56(4):253-270. (ADF&G, Habitat Library, #R2678.)

Changes in the size composition of spawning bed materials in six coastal streams were monitored for 3 yr to determine the effects of logging on the habitat of silver salmon and rainbow and cutthroat trout. Four test streams were sampled before, during, and after logging. Two streams in unlogged watersheds and the undisturbed upstream section of one test stream served as controls. A variety of stream types in second-growth and old forests was selected for observation.

Spawning bed composition in the four test streams changed after logging, roughly in proportion to the amount of streambank disturbance. The heaviest sedimentation occurred when bulldozers operated in narrow stream channels having pebble bottoms. In a larger stream with a cobble and boulder bottom, bulldozer operations in the channel did not increase sedimentation greatly. Sustained logging and road construction kept sediment levels high in one stream for several years. Sedimentation was greatest during periods of road construction near streams and removal of debris from streams, confirming the need for special measures to minimize erosion during such operations. Control streams changed little in spawning bed composition during the 3 yr. (Author's abstract)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. Tran. Am. Fish. Soc. 101(1): 1-17. (ADF&G, Habitat Library, #R3024.)

The effects of logging and associated road construction on four California trout (rainbow and steelhead) and salmon (coho) streams were investigated from 1966 through 1969.

Removal of too much forest canopy can have drastic consequences for salmonids due to warmer water temperatures. Elevation of water temperatures raises metabolic rates and maintenance requirements, increases pathogenic activity, and decreases oxygen solubility.

Extensive use of bulldozers on steep slopes or in stream channels can cause excessive erosion and compaction of the stream bed, which can be deleterious to salmonid reproduction. Small streams with narrow channels seem most vulnerable to this type of damage. Building roads away from the stream or leaving a buffer strip to intercept sediments and slash protects the stream habitat. Seeding the disturbed areas with grass mitigates the damage.

Excessive erosion from logging fills pools necessary for the rearing of larger salmonids. In this study, pools filled with sediment caused from logging were scoured each winter, when logging and road-building were not occurring, providing living space the following year. However, numerous sediment bars were formed, which constituted an unstable streambed.

Logging resulted in higher peak stream flows and more rapid attainment of peaks.

The author points out that the time of year when logging occurs is important. Felling trees into a stream when embryos and fry are in the gravel introduces decaying slash, which depletes intragravel dissolved oxygen or produces large amounts of slime bacteria, which suffocate developing young. The author stresses the need to keep all timber out of streams, not only to prevent log jams but also to allow flushing of sediments.

Logging operations should be completed in the shortest time possible and the watershed then left to recover.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation.

Burrell, D.C., and D. Welhs. 1983. Uptake of cadmium by marine bacteria and transfer to a deposit feeding clam. Rept. No. 82-3, Inst. Mar. Sci., Fairbanks, AK. (ADF&G, Habitat Library, #B6249.)

This laboratory study evaluates one potential pathway whereby sediment-derived cadmium - a toxic element of no known biological utility - may be taken up by the secondary benthos and then transferred directly to man.

Two concentrations of inorganic cadmium (0.1 and 1.0 ug/l), spiked with ^{109}Cd tracer, were added to mono-specific marine bacteria cultures during the log growth phase. Uptake of the cadmium by or onto the bacteria cells was in the range of 87 to about 100% complete (mean of 96% for six experiments). These bacteria were subsequently presented as the sole additional food source to batches of deposit-feeding clams (Macoma balthica) maintained in 11°C aquaria for periods ranging from 14 to 54 d.

Test specimens were starved prior to each experiment, and feeding behavior appeared to be normal, but the feeding rate could not otherwise be controlled. At the conclusion of each experimental run, the ratio of cadmium associated with the (non-acidleached) shells to that held by the tissue ranged from 10 to 50%, suggesting sorption of cadmium (bacteria) onto the shell material. Within the clams, cadmium was found to be concentrated nearly 20x more in the (purged) stomach tissue than in the remaining soft parts. Elevated concentrations of radiocadmium in the aquaria waters (1-23 ug/l) are attributed to suspension of organic-rich particulate sediment.

The experimental results deomonstrated that this deposit-feeding clam may ingest (via an identified major food source) and accumulate a nonessential, toxic metal. However, food web biomagnification was not demonstrated here, although tissue concentrations of cadmium increased to one or two orders of magnitude over that present in the substrate and the ambient water (the latter defining the conventionally defined "concentration factor"). Because there was no evidence for elimination of cadmium via the feces, a long biological half-life for the tissue-accumulated cadmium is indicated. Tissue concentrations of approximately greater than 12 ug/g resulted in 50% mortality of the test clams.

Activity: dredging; processing minerals.

Impact: change in levels of heavy metals.

Burroughs, E.R., Jr., M.A. Marsden, and M.F. Haupt. 1972. Volume of snowmelt intercepted by logging roads. Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers. 13 pp. (ADF&G, Habitat Library, #R3841.)

The results of this study indicate that during an average snowmelt season at high elevation near the Montana-Idaho border the daily melt volume can be of considerable magnitude. A significant portion of this daily snowmelt can enter the road as overland flow if the winter-spring water table is sufficiently high that the soil mantle cannot accommodate the daily snowmelt.

These results suggest that roads constructed in regions with intense snowmelt seasons and with areas that exhibit a potential for overland flow should have special attention given to preventing erosion of cut and fill slopes by this overland flow. The seepage force of subsurface water moving from the soil into the road section may cause frequent slumping of the cut slope. Finally, consideration should be given to the effect of large volumes of road drainage water on the shape of the basin hydrograph. (Author's abstract)

Activity: grading/plowing.

Impact: change in depth or velocity of water.

Burton, T.M., R.R. Turner, and R.C. Harriss. 1976. The impact of highway construction on a north Florida watershed. Water Res. Bull. 12(3): 529-538. (ADF&G, Habitat Library, #R1900.)

A 20-mo study of some effects of highway construction on water quality was conducted during construction of Interstate 10 at Tallahassee, Florida. Highway construction resulted in significant increases in turbidity, suspended solids, total phosphorus,and dissolved silicon in downstream waters despite use of recommended procedures for erosion control. Highway construction did not result in significant increases in dissolved phosphorus or nitrogen. (Authors' abstract)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; change in levels of nutrients.

Bustard, D.R., and D.W. Narver. 1975a. Preferences of juvenile coho salmon (Oncorhynchus kisutch) and cutthroat trout (Salmo clarki) relative to simulated alteration of winter habitat. J. Fish. Res. Bd. Can. 32:681-687. (ADF&G, Habitat Library, #R5081.)

Winter habitat preferences of juvenile coho salmon (Oncorhynchus kisutch) and cutthroat trout (Salmo clarki) were tested by simulating conditions before and after stream disturbance such as might result from logging: 1) sidepools with or without an overhanging bank and roots and 2) sidepools with clean or silted rubble substrate. Both coho and cutthroat demonstrated a strong preference for sidepools offering overhanging bank cover as opposed to those without bank cover. Similarly, they preferred sidepools with clean rubble substrate as opposed to silted rubble. In both the bank and rubble tests, when given the option of either remaining in the sidepools or of moving into the stream, a greater percentage of the total number of coho and cutthroat originally in the sidepools remained in the pools with cover as opposed to those without cover. Coho utilized bank cover more readily than rubble cover, whereas cutthroat used both bank and rubble cover. (Authors abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; alteration of natural cover - overhanging bank or shoreline.

Bustard, D.R., and D.W. Narver. 1975b. Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). J. Fish. Res. Bd. Can. 32:667-680. (ADF&G, Habitat Library, #R5082.)

The major physical characteristics of overwintering areas for juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri) are described for a small, unlogged, west coast Vancouver Island stream. During the winter months age I+ coho and steelhead were found at a range of depths mainly greater than 45 cm and in deeper water than age 0 of either species. About 45% of age 0 steelhead observed were in water less than 15 cm deep. The depth occupied by coho and age I+ steelhead was negatively correlated with water temperature below 8.5°C. Coho were associated less closely with the bottom than were steelhead. At 7°C or less most fish were associated with water velocities of less than 15 cm/s. Velocities in which steelhead occurred were positively correlated with rising temperature above 4°C. As water temperature decreased from 9 to 2°C, coho and steelhead moved closer to cover. Cover used by coho and age I+ steelhead most frequently was logs and upturned tree roots, although debris accumulations and overhanging banks were also used. Both age groups of coho used overhanging brush but steelhead did not. Over 50% of age 0 steelhead were associated with rocks 10-25 cm in diameter. Sidepools and quiet back channels that contained water only in the winter and that had combinations of the above cover types were populated by coho during the winter. A series of unused beaver ponds, dry in the summer, was an important overwintering area for coho, with a survival rate about twice as high as the 35% estimated for the entire stream system. (Authors abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation.

Cabioch, L., J.C. Dauvin, F. Gentil, C. Retiere, and V. Rivain. 1981. Perturbations induites dans la composition et le fonctionnement des peuplements benthiques sublittoraux, sous l'effet des hydrocarbures de l'Amoco Cadiz. (Perturbations induced on the composition and functioning of the sub-littoral benthic populations by Amoco Cadiz hydrocarbons.) In Amoco Cadiz: Fates and effects of the oil spill. Proceedings International Symposium. Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4330.)

The effects of hydrocarbons were observed at various sites, selected after comparing the condition of the sublittoral benthic communities during 1978 with their condition before the pollution. A quantitative and dynamic study of the populations undertaken 1 yr before the Bay of Morlaix became polluted provided a guide to bring together the interpretation. An essential part of the project was the study of the communities of fine sediments most affected by the oil.

The results obtained from the study of the first annual cycle after the pollution led to the following principal conclusions:
° All areas were impacted by a brief immediate phase of selective mortality, which affected a limited number of species (principally Crustaceans, Molluscs, and Echinocardium) and which mainly disturbed the communities of the fine sediments. In the case of species sensitive to hydrocarbons and that were very abundant, there was a great loss of biomass and production.

° In the moderately disturbed sites, most of the surviving species followed afterwards an apparently normal annual cycle. Nevertheless, we observed some interruptions to the recruitment of some species; these involved more species in the very polluted fine sands.

° A transient proliferation of a more lasting rise in the density of certain Polychaetes (particularly the Cirratulidae and Capitellidae) was observed.

° At the end of the first annual cycle, recolonization by the most important species that had been catastrophically eliminated had not yet taken place.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Cameron, J.A., and R.L. Smith. 1980. Ultrastructural effects of crude oil on early life stages of Pacific herring. Trans. Am. Fish. Soc. 109: 224-228. (ADF&G, Habitat Library, #R3860.)

Cameron and Smith exposed eggs of Pacific herring from Prince William Sound, Alaska, to Prudhoe Bay crude oil for 4 to 144 h and then returned the eggs to uncontaminated sea water for further development. Newly hatched larvae from both control and experimental groups showed no gross abnormalities. However, there were significant differences in the ultrastructural appearance of these groups. Broken mitochondria in the group exposed to oil could affect repiration and metabolism and result in loss of energy during the larval stage. The swollen condition observed in mitochondria in the exposed group suggests a change in the osmotic balance and is a sign of cell damage. The cellular disruptions noted in herring exposed to oil could severely decrease survival potential for the larvae, especially as energy demands for growth, feeding, and predator avoidance at this stage are high.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Campbell, H.J. 1954. The effect of siltation from gold dredging on the survival of rainbow trout and eyed eggs in Powder River, Oregon. Oregon State Game Commission. 3 pp. (ADF&G, Habitat Library, #R3757.)

This brief paper discusses the impacts of rainbow trout and eyed eggs caused by gold-dredge sediments.

In waters where suspended sediment concentrations fluctuated between 1,000 and 2,500 ppm, eyed rainbow trout eggs were destroyed within a 6-d period. Rainbow trout fingerlings exposed to these sediment concentrations sustained 57% mortality over a 20-d period.

Turbidity ranges from 3,000+ ppm at the dredge to 400 ppm were found to preclude any recreational use of the river for a distance of about 40 mi.

Activity: dredging; processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Campbell, K.L., S. Kumar, and H.P. Johnson. 1972. Stream straightening effects on flood runoff characteristics. Trans. Am. Soc. Agric. Eng. 15(1):94-98. (ADF&G, Habitat Library, #R5093.)

The purpose of the study was to evaluate the effects of stream straightening and diking on flow characteristics of storm runoff effects. In this study of the Boyer River in western Iowa, the emphasis was on flood-routing (peak discharge, flood-wave travel time, and duration of flooding). Many Iowa rivers have been straightened and diked to achieve drainage and flood control on riparian land. The results of the study indicate that the straightening and diking of natural streams increases the magnitude of the peak discharge (90-180%) and significantly shortens the time base of the discharge hydrography. It also greatly reduces the time of travel of the flood wave down the river. The magnitude of these effects depends upon the length of the river involved and the characteristics of the river, such as shape of channel, degree of meandering, shape of flood plain as it affects the temporary storage capacity, vegetation on the flood plain as it affects the roughness, and slope of the valley.

Activity: channelizing waterways; draining.

Impact: change in depth or velocity of water.

Canada Department of Fisheries and International Pacific Salmon Fisheries Commission. 1966. Effects of log driving on the salmon and trout populations in the Stellako River. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 14. Vancouver, B.C., Canada. 88 pp. (ADF&G, Habitat Library, #B6185.)

Field and laboratory investigation of effects of log driving on the fish populations of Stellako River were carried out during 1965. Field studies showed that log jams cuased damage to approximately 8% of sockeye spawning grounds (23,800 yd^2) by erosion of gravel and bark deposition. That the damage was real was verified through analysis of subsequent spawning distribution which showed that spawners tended to avoid the damaged areas. Laboratory results indicated that moderate gravel disturbance due to erosion and gouging by individual logs could also have killed incubating trout eggs in Stellako River, but that vertical impact on the gravel surface would have cuased only occasional mortality. (Author's abstract)

Activity: log storage/transport.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in levels of other toxic compounds - bark or log leachates.

Canevari, G.P., and G.P. Lindblom. 1976. Some dissenting remarks on deleterious effects of Corexit 9527 on fertilization and development. Mar. Pollut. Bull. 7(7):127-128. (ADF&G, Habitat Library, #R0206.)

This is a reply to the article by Lonning and Hagstrom that, based on laboratory testing, concluded that Corexit had a deleterious effect on sea urchin and fish fertilization and development. The authors point out first that a concentration of 1-10 ppm of chemical dispersant does not normally occur in the marine environment with proper use of the dispersant and second, that there is no evidence to support the conclusion that the specific chemical dispersant studied by Lonning and Hagstrom preferentially releases toxic substances from the crude oil. They conclude that without a more complete and realistic identification of the risk of chemical dispersants there should be no overall reluctance to use them, particularly where spawning is not endangered.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Caplice, O. 1959. Effects of placer mining (dredging) on a trout stream. Pages 63-97 <u>in</u> Annual progress report, Project F-34-R-1. Water Quality Investigations, Fed. Aid in Fish Rest. Idaho Department of Fish and Game, Moscow. (ADF&G, Habitat Library, #R2825.)

A 3-yr study to measure the chemical, physical, and biological changes brought on by dredge mining is the subject of this paper. Chemical (dissolved oxygen, pH, alkalinity) changes in the water were not detected. Physical changes included a rise in water temperature below the dredged area, reduction in the area available to fish by shortening of the stream, elimination of pools through channel straightening, filling in of the pools with silt, and a decrease in the value of the riffles for spawning. Biological changes were greatest during the dredging activity. Aquatic insects and fish were reduced 99% during dredging but recovered within 1 yr. Aquatic insects 0.3 m below the dredge were not affected. Whitefish were most adversely affected by dredge; suckers increased in numbers below the dredge.

Activity: channelizing waterways; dredging; processing minerals.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness.

Cardwell, R., and R. Koons. 1981. Biological considerations for the siting and design of marinas and affiliated structures in Puget Sound. Wash. Dept. Fish., Tech. Rept. No. 60. (ADF&G, Habitat Library, #B1927.)

The ecology and biology of several economically and ecologically important fish and invertebrates is discussed relative to several ways they could be affected adversely by the construction of marinas and affiliated structures (e.g., bulkheads). Succeeding sections describe and justify means for reducing or precluding these biological impacts by siting and designing marinas and bulkheads in biologically less sensitive areas.

In the greater Puget Sound basin, littoral habitats are used for spawning, rearing, migration corridors, and refugia from predators by a large number of fish and invertebrates. Means are discussed for protecting not only these uses but also the viability of the invertebrates that are preyed upon by fish (e.g., Pacific salmon juveniles), the physical character of the substrate, and the harvestability of subtidal beds of clams. The latter could be precluded if coliform bacteria concentrations associated with marina boat traffic rise above water quality standards. (Author's abstract)

Activity: filling and pile-supported structures (aquatic and wetland habitats).

Impact: addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen.

Cardwell, R., M. Carr, S. Olsen, and E. Sanborn. 1978. Water quality and biotic characteristics of Birch Bay Village Marina in 1977. Washington Dept. Fish. Prog. Rept. No. 69. (ADF&G, Habitat Library, #B6562.)

This project sought to assess the impacts of a marina in north Puget Sound, Washington, on fish, plankton, and water quality. The Birch Bay Village Marina was visited eight times at approximately monthly intervals from March to September 1977. Fish and macrozooplankton communities captured during the day and night in the marina and adjoining Birch Bay were characterized for composition and abundance, whereas water quality measured at discrete locations and times was compared to measurements made continually in the innermost portion of the marina.

The marina's water quality was generally equivalent to that of the bay. Most notable were seasonal elevations in temperature, reductions in salinity, and slight elevations in the level of contamination of caged groups of Pacific oysters with fecal coliform bacteria. Discrete water quality sampling produced results comparable to continuous sampling.

The viability and standing crop of the marina phytoplankton community was similar to that of the bay, but the macrozooplankton community was less diverse and rich in species and possessed a lesser standing crop. Amphipods, crab larvae, and cumaceans were more abundant in the marina, but copepods and fish eggs were less abundant. In the surface waters, macrozooplankton was markedly more abundant during the night in both habitats.

The marina's fish community was also less diverse and rich in species than that in the bay, and it possessed a lesser standing crop. However, there were few major differences in the densities of the major species present between habitats. Chum and chinook salmon, surf smelt, Pacific herring, and Pacific sand lance were among the most economically or ecologically important species congregating in the marina during their larval or juvenile stages, or both. A limited marking study with chum salmon juveniles suggested most (about 88%) of the marked fish had left the marina within 5 d of release, but also revealed a notable, though steadily declining, residual population remaining for at least 33 d.

Predation upon juvenile salmon by fish judged large enough to consume them was not detected. Spiny dogfish and chinook and chum salmon were important predators of larval and small juvenile herring, but staghorn and great sculpins, the species considered potential predators of juvenile salmonids, preyed largely or exclusively on invertebrates. (Author's abstract)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; addition of physical barriers - partial obstructions.

Cardwell, R., M. Carr, and E. Sanborn. 1980a. Water quality and flushing of five Puget Sound marinas. Wash. Dept. Fish. Tech. Rept. No. 56. (ADF&G, Habitat Library, #B6245.)

Quantitative relationships between water quality and flushing were investigated for five Puget Sound, Washington, marinas in an attempt to define minimum flushing standards. Recognizing that such standards should also depend upon the quality of the source water, we analyzed 2-yr sets of water quality and 30-yr sets of climatologic data in an attempt to predict surface water quality based upon the historical climatic record. Water temperature and dissolved oxygen (D.O.), associated variables (e.g., chlorophyll a), and flushing indices were the parameters considered.

Marina water temperatures and oxygen contents increased as flushing decreased, but no statistically reliable bivariate functions could be derived. All marinas except Squalicum typically possessed higher temperatures than those of the source waters, but the magnitudes decreased from early to late summer. Several marinas violated state water temperature standards, and mean exchange coefficients of 25% or more seem necessary to preclude these violations. The standard must be flexible because source water temperatures as well as marina temperature increases are criteria. Puget Sound surface (3.1 m depth) water temperatures may be predicted with high precision using the mean 7-d air temperature (AIRT7). The equation TEMP(°C) = 3.299 + 0.729(AIRT7,°C) appears useful for general application in the Puget Sound basin, but more site-specific equations should be used when possible. Marina D.O.s were higher than those of the source waters in the two most poorly flushed marinas, a result of augmented phytoplankton crops. In late summer, subsurface (2.1-3.1 m) oxygen contents in all five marinas fell at night to levels that violated state standards and probably imposed severe hypoxia on some organisms. In order to prevent pronounced nocturnal D.O. declines, marina flushing must be sufficient to preclude phytoplankton blooms. For this purpose, gross exchange coefficients should average at least 30%. (Author's abstract)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in level of dissolved oxygen, nitrogen.

Cardwell, R., S. Olsen, M. Carr, and E. Sanborn. 1980b. Biotic, water quality and hydrologic characteristics of skyline marina in 1978. Wash. Dept. Fish. Tech. Rept. No. 54. (ADF&G, Habitat Library, #B1926.)

Fish, zooplankton, and water quality characteristics of Skyline Marina in north Puget Sound were compared to the marina's source water in monthly surveys conducted from March to October 1978. A companion study defined the marina's flushing properties. Fish were indexed mainly by purse seining and the food habits of seven species of salmon (Oncorhynchus spp.) and baitfish juveniles in terms of ontogenic-seasonal variation. Symbol surface zooplankton larger than 505 um were indexed with push nets. Water quality was described through measurements of general parameters (e.g., temperature, phytoplankton, nutrients), heavy metal and organic concentrations in sediments, heavy metal residues in adult Pacific oysters (Crassostrea gigas), and acute toxicity of ambient waters to Pacific oyster larvae.

The marina's fish populations were numerically larger, more diverse and rich in species than those in the bay. The majority of the Pacific herring (Clupea harengus pallasi), coho salmon (O. kisutch), and chinook salmon (O. tshwaytscha) were captured within the marina, whereas most pink (O. gorbuscha) and chum (O. keta) were captured in Burrows Bay. An experimental release of marked chum salmon fry into the marina suggested rapid emigration and a median residence time of 1 wk or less. Predation on baitfish and salmon juveniles in the marina was judged to be low due to an apparent scarcity of potential bird and fish predators during the period of maximum juvenile fish abundance (May-September).

Surface zooplankton in the marina were less dense and rich in species than those in the bay, and several holoplanktonic species--e.g., siphonophores and tunicates--were either absent or present in reduced densities. Calanoid copepods, the primary prey of chum and pink salmon, surf smelt (Hypomesus pretiosus), and Pacific herring were most abundant in the bay. Conversely, the principal prey of chinook and coho salmon, brachyura and teleost larvae, were most abundant in the marina.

The amounts of Skyline Marina water exchanging with the source water were among the lowest on record for Puget Sound marinas, being 8, 20, and 40% for 0.76, 1.52, and 2.90 m tidal ranges.

Skyline Marina had warmer temperatures, higher concentrations of dissolved oxygen (D.O.), chlorophyll, ammonia, copper in the sediments, and copper and zinc in adult oysters, and lesser concentrations of nitrite-nitrate and ortho-phosphate than Burrows Bay. Water quality was most variable from June through August, the general period for concern about water quality problems in marinas. Diel changes in surface D.O.s were pronounced in July relative to other months, ranging from 17 mg/l during the day to 12 mg/l at night. At no time, however, did marina D.O.'s or temperatures attain inimical levels. Though elevated residues of zinc and copper were measured in oysters held in the marina, presumedly due to leaching of these metals from vessel antifouling paints, significance remains to be established. (Author's abstract)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of nutrients.

Carline, R.F., and S.P. Klosiewski. 1985. Responses of fish populations to mitigation structures in two small channelized streams in Ohio. N. Am. J. Fish. Mgt. 5:1-11. (ADF&G, Habitat Library, #R5134.)

Responses of fish populations to mitigation structures (rock deflectors and artificial riffles) were compared in two small channelized streams in Ohio to determine potential recreational benefits of such structures. In Chippewa Creek, we compared fish populations 1 and 3 yr after construction in sections with and without rock deflectors. In River Styx, previously altered around 1950, we compared fish fauna 1 yr before and 1 yr after channelization in sections with and without mitiation devices. Sections with rock deflectors in Chippewa Creek supported significantly more species and higher numbers and biomass of fish than did sections without structures. In River Styx, fish populations before construction and 1 yr afterwards were similar; low flows prior to channelization and above-average flows afterwards probably had more influence on fish populations than the habitat changes. Stations with deflectors or artifical riffles tended to support greater densities of fish than stations without mitigation structures, although differences were not statistically significant. Deflectors created appartently favorable habitat for centrarchid species, yet their small sizes (primarily juveniles) and low densities in both streams provided limited sportfishing opportunities. We hypothesized that the primary limiting factor for the centrarchids was reproductive failure due to erratic flows rather than inadequate habitat. (Author's abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water.

Carls, M.G., and S.D. Rice. 1980. Toxicity of oil-well drilling muds to Alaskan larval shrimp and crabs. Pages 1-36 in Environmental assessment of the Alaskan continental shelf. Final reports of principal investigators. 1981. Vol. 2: Biological studies. 670 pp. (ADF&G, Habitat Library, #R3872.)

Crab and shrimp larvae were tested to determine the toxicity of six drilling muds and water-soluble fractions of muds. The species tested were king crab (Paralithodes camtschatica), Tanner crab (Chionoecetes bairdi), Dungeness crab (Cancer magister), coonstripe shrimp (Pandalus hypsinotus), dock shrimp (Panalus danae), and kelp shrimp (Eualus suckleyi). Drilling muds affect larval crustacean swimming ability and survival. The water-soluble fractions of drilling muds are stable in solution, but oil water-soluble fractions are not. The slow nature of the drilling mud toxicity suggests the toxic components are not very active as chemical poisons but cause extra larval energy expenditure to maintain homeostatis. Accelerated energy depletion results in early death. Crustacean larvae are more sensitive to drilling muds than adult crustaceans and fish by approximately an order of magnitude. Water column concentrations of drilling muds capable of causing toxicity are probably brief and limited to distances less than 3 m from the point of platform discharge. The authors conclude that, under most conditions, drilling mud discharge has no measurable impact on marine planktonic and nectonic communities.

Activity: drilling.

Impact: change in levels of heavy metals; change in levels of other toxic compounds - other.

Carls, M.G., and S.D. Rice. 1984. Toxic contributions of specific drilling mud components to larval shrimp and crabs. Mar. Environ. Res. 12:45-62. (ADF&G, Habitat Library, #R3680.)

Carls and Rice investigated the toxicities of six drilling muds, toxicities of mud fractions (supernatants and suspensions), and the toxicities of common mud components--barite and bentonite (particulates) and ferrochrome lignosulfonate (soluble)--to the stage I larvae of six species of shrimp and crab. The drilling muds tested were not very toxic to these larvae: LC50s for supernatants ranged from 0.6 to 82% (vol/vol). Shrimp larvae were slightly more sensitive than crab larvae.

Drilling muds were not rapidly toxic, in contrast to toxicants such as the water-soluble fractions of oil. Supernatants, prepared by centrifuging whole muds, were mildly toxic. Suspensions were more toxic than supernatants, and toxicity was greatest when particulates remained suspended: for example, used Cook Inlet mud suspensions were about seven times more toxic than supernatants. The toxicity of used Cook Inlet mud was therefore primarily due to suspended solids (88%) rather than chemical toxicity: ferrochrome lignosulfonate was relatively toxic alone but accounted for only about 6% of the toxicity of used Cook Inlet mud suspensions. Contributions of particulates to mdu toxicities varied considerably. Barite and bentonite were not very toxic when tested alone. The toxicity of one mud was caused by its high alkalinity. (Author's abstract)

Activity: drilling.

Impact: change in levels of heavy metals; change in levels of other toxic compounds - other; change in levels of hydrocarbons.

Carstea, D., A. Binder, R. Strieter, L. Boberschmidt, L. Thomas, and J. Golden. 1975. Guidelines for the environmental impact assessment of small structures and related activities in coastal bodies of water. U.S. Army Corps of Engineers, New York District, Proj. No. 8960. The Mitre Corp., McLean, Virginia. 213 pp. (includes appendices). (ADF&G, Habitat Library, #B6202.)

This is a guideline document that develops documented quantitative data from existing coastal development projects to estimate and predict environmental impacts from a given type of activity in similar project sites. The report describes probable environmental impacts of shoreline alteration structures and the activities associated with their construction, maintenance, and use. The authors provide procedural and technical guidelines for an effective environmental assessment of specific proposed projects. Shoreline structures addressed are riprap, bulkheads, groins and jetties, piers, mooring piles, ramp construction, dredging, outfalls, submerged lines and pipes, and aerial crossings. Data and information were obtained from 1,000 permit requests from the U.S. Army Corps of Engineers New York District office. The project sites were all located along the coast of the northeastern United States.

For clarity, the authors generally characterize the physical, chemical, and biological nature of the aquatic environments of the northeastern Atlantic coastline.

A companion report is available with guidelines and impact assessments specific to the Gulf of Mexico coastal zones.

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen; change in level of salinity; change in levels of heavy metals; change in levels of other toxic compounds - other; change in levels of nutrients.

Castilla, J.C., and E. Nealler. 1978. Marine environmental impact due to mining activities of El Salvador copper mine, Chile. Mar. Pollut. Bull. 9(3):67-70. (ADF&G, Habitat Library, #R3922.)

Marine environmental impact as a result of copper mine tailing dumping in the sea was studied ad Chanaral (north of Chile). These dumpings, from the copper mine El Salvador, have hindered harbour activities, caused geomorpho logical coastal modifications, and seriously affected marine coastal ecosystems and recreational activities. At the old dumping site, Chanaral Bay, nearly 150 million tons of fine sediments were accumulated. Tailing discharges at the new dumping site, Caleta Palito, about 8 km north of Chanaral Bay, are accumulating approximately at the rate of 25,000 tons of fine sediment per day, plus unknown quantities of chemicals (copper, arsenic). From January 1975 to July 1976, this site received over 13 million tons of sediments, which has caused deterioration of the marine coastal environment, reduction in light penetration, and high mortalities among marine invertebrates (starfish, limpets, sea urchin, crabs), fishes (several species identified only by Latin name), and algae. (Author's abstract: modified)

Activity: solid waste disposal.

Impact: change in levels of heavy metals.

Cederholm, C.J. 1972. The short-term physical and biological effects of stream channelization at Big Beef Creek, Kitsap County, Washington. M.S. Thesis, Univ. Washington, Seattle. 91 pp. (ADF&G, Habitat Library, #R1742.)

During the summer of 1969, the lower 0.5 mi of Big Beef Creek was channelized, ostensibly to improve salmon and trout spawning and rearing habitat and for flood control. Channelization was carried out using two bulldozers and other heavy equipment to straighten and narrow the high-flow stream channel. The artificial dikes within the channelized area were made of streambed gravels. There was much erosion of the diked banks during high-flow periods. Two years after stream channelization, 54% (2,987 m^3) of the sediments deposited in the channelized area came from erosion of these dikes coupled with streambed degradation within the channelized area. Due to a greatly increased streambed slope and the confining of flow by the dikes, the streambed had high rates of scour and fill. The channelized area was not improved measurably as a spawning habitat. (Annotation from Stearn and Stearn 1980b)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Cederholm, C.J. 1977. The impact of logging on salmonid resources in the Pacific Northwest. Pages 101-111 in Twenty-eight northwest fish culture conference, Univ. Washington, Seattle, Fisheries Research Institute. Dec. 6-8, 1977. (ADF&G, Habitat Library, #R3835.)

Some logging practices have been found to cause degradation to the watersheds and result in impacts to salmonid resources. For convenience, logging activities affecting fisheries resources can be divided into four categories:

1. Road Construction and Maintenance

   a. Siltation of the spawning and rearing substrates with sand-sized and smaller particles can decrease intragravel survival of salmonid eggs and embryos and reduce postemergent fitness, and fill intra-gravel spaces used by fry and other aquatic organisms as hiding cover during the summer and winter months.

   b. Suspended sediment (turbidity) at very high levels has been found to cause physical abrasion to the respiratory structures of fish and aquatic insects, affect the feeding behavior of coho salmon smolts; and reduce the photosynthetic processes of aquatic algae by inhibiting light penetration to the stream bed.

   c. Also related to road construction at stream crossings are serious juvenile and adult migration blockages.

   d. Road construction and maintenance can also cuase sluiceouts and landslides to occur in small, steep headwater streams because of alterations in natural drainage patterns.

2. Forest Canopy and Residue Removal

   a. Logging of large openings in watersheds has been found to increase streamflows and in some cases cause more rapid attainment in peak flows during fall freshets, these increased flows can cause additional streambed scour which can result in the loss of salmon eggs and larvae; cause daily mean and maximum summer temperatures to reach the upper lethal limits; and cause winter temperatures to be further depressed to near threshold limits.

   b. Logging across and through streams can cause large amounts of fine organic material to enter the stream, and this debris can have a high biological demand for dissolved oxygen that would otherwise be available to fish; the entry of large organic debris into streams, which can cause erosion of embankments, logjams that block adult and juvenile migration, and cover spawning and rearing areas; and physical damage to the stream bed and embankments during log yearding, which results in adiditional sedimentation and unwanted stream alterations.

3. Addition of Chemicals, Including Herbicides and Fertilizers

   Under proper use, there are no known instances of significant damage to aquatic ecosystems from the application of presently registered herbicides used in silviculture. However, herbicides used in alder suppression along streams may substantially affect litter, terrestrial food to fish, and nitrogen and bank stabilization provided by vegetation.

4. Log Storage and Transportaion

   The following are some of the environmental impacts of log handling on fresh water: significant quantities of bark are dislodged during log dumping and rafting activities. Bark deposits exert a small but measurable chemical and biological demand for oxygen from overlaying water. Organic compounds leach from logs when stored in water. Log leachates exert a chemical biological oxygen demand. Log leachates add color-producing substances to the water. Douglas fir leachates are acutely toxic to rainbow troug and chinook salmon fry in fresh water.

Federal and state laws that have been adopted to control logging practices and their effects on salmonid resources are briefly covered, and some thoughts concerning future research needs are discussed.

Activity: chemical application; clearing and tree harvest; grading/plowing; log storage/transport.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation; addition of physical barriers - partial obstructions; change in levels of biocides; change in levels of other toxic compounds - bark or log leachates.

Cederholm, C.J., and K V. Koski. 1977. Effects of stream channelization on the salmonid habitat and populations of Lower Big Beef Creek, Kitsap County, Washington 1969-73. Washington Cooperative Fishery Research Unit, College of Fisheries, Univ. Wash., Seattle, WA. 31 pp. (ADF&G, Habitat Library, #B6559.)

The physical and biological effects of stream channelization on Big Beef Creek, Kitsap County, Washington, were investigated from 1969 through 1973. The lower 0.6 km of Big Beef Creek was channelized by bulldozers to reduce the problems of flooding, redd displacment, and loss of fish-rearing habitat. This situation offered an excellent opportunity to document the streambed, fisheries habitat, and population changes caused by alteration and the time rquired for recovery.

This study included measurements of streambed scour and fill, streambank erosion, pool-riffle composition, streambed and streambank cover, streambed slope, summer low-flow density for coho salmon and steelhead trout, and spawning success of chum salmon.

Channelization was found to be incompatible with good anadromous fish production. The extensive streambed scour and streambank erosion rates in the channelized area caused by man's alterations resulted in a highly unstable stream environment. The total sediment contribution from within the channelized area (6570 m^3/km) due to erosion processes was 7.6 times greater than the rate in the unchannelized upstream areas (870 m^3/km) over the 4-yr period of measurement. Much of the important fish habitat characteristics of streambank cover, log jam occurrence, and stream pools and riffles was completely lost during the initial alteration and has shown varying rates of recovery.

The density of juvenile salmonids was greatly reduced for at least the first two summers following alteration. During the second summer following channelization, the coho salmon densities (0.718 fish/m^2) were 75% lower than the control (2.925 fish/m^2); the steelhead age 0 densities (0.526 fish/m^2) were 77% lower (1.290 fish/m^2), and the age 1+ densities (0.020 fish/m^2) were 96% lower (0.470 fish/m^2).

The coho salmon populations showed remarkable signs of recovery after three summers, whereas the steelhead trout have been slow to recover even after five summers.

The resulting instability in the spawning gravel environment caused the loss of 55% of the chum salmon redds spawned within the channelized area during the winter of 1970-1971.

Alteration of lower Big Beef Creek through channelization resulted in a highly unstable stream environment that has not fully recovered after 5 yr. Research should be undertaken to develop wise techniques for fisheries habitat improvement for northwest streams. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. Pages 38-74 in Proceedings from the conference on salmon-spawning gravel: a renewable resource in the Pacific Northwest? Rept. #39, Washington State Univ., State of Washington Water Research Center, Pullman. (ADF&G, Habitat Library, #R2834.)

The nature of sediment production from logging roads and the effect of the resulting sediment on salmonid spawning success in the Clearwater River drainage have been studied for 8 yr. The study includes intensive and extensive analyses of field situations, supplemented by several controlled experiments. It was found that an increase (15-25%) of fine sediments (less than 0.85 mm diameter) were accumulating in gravels of some heavily roaded tributary basins. This accumulation is highest in basins where the road area exceeds 2.5% of the basin area. Tributaries of relatively steep gradient are less likely to accumulate high levels of fines. The survival of salmonid eggs to emergence is inversely correlated with percentages fines when the percentage of fines exceeds the naturally occurring levels of 10%. There is a rapid decrease in survival to emergence for each 1% increase in fines over natural levels. The presence of 2.5 km/km^2 of gravel-surfaced roads undergoing an average distribution of road uses is found to be responsible for producing sediment at 2.6-4.3 times the natural rate in a drainage basin. Sixty percent of the road-related sediment production is caused by landslides, and erosion on road surfaces accounts for an additional 18-26%. If fine sediment alone is considered, production from road surfaces and landslides is nearly equal. Production of fine sediment from road surfaces and landslides is nearly equal. The tributaries of the Clearwater River may be underseeded for coho salmon because of heavy harvest rates in the commercial and sport fisheries. This depressed population condition becomes significant when considering the depressed efficiency of the spawning environment due to logging-caused sedimentation. (Author's abstract: modified)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

Chamberlin, T.W. 1982. Timber harvest. Vol. 3 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Series: 1979-. USDA: Forest Service. Pacific Northwest Forest and Range Experiment Station, Portland, OR. Gen. Tech. Rept. PNW-136. 30 pp. (ADF&G, Habitat Library, #B2439.)

The water- and land-system processes through which timber harvesting affects anadromous fish habitat in western North America are discussed. The effects of timber harvesting on the water balance that regulates streamflow are evaluated, as are direct influences of harvesting on slope stability, erosion, and the introduction of debris into stream channels.

A summary of the major effects of timber harvest on stream habitat is as follows. Timber harvest activities result in the acceleration of erosion and mass movement of soil, the introduction and removal of organic debris, the alteration of channel shape, and the removal of streamside vegetation. In turn, these alterations generally result in increases in the depth and velocity of water in streams, increases in the summer water temperature and decreases in the winter water temperature, increases in the concentrations of suspended sediments and nutrients, a reduction in the quality of the gravels for successful incubation of salmon embryos, and substantial changes in the type and quality of stream cover for fish (some gains, some losses).

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen; change in levels of nutrients.

Champ, M.A., T.P. O'Connor, and P.K. Park. 1981. Ocean dumping of seafood wastes in the United States. Mar. Pollut. Bull. 12(7):241-244. (ADF&G, Habitat Library, #R3859.)

This paper outlines historic and current United States laws pertaining to ocean-dumping of seafood wastes and contains a short section on current dumping practices in Alaska. It also summarizes characteristics of seafood wastes and gives a chemical analysis of fish wastes to be ocean-dumped off American Samoa. Impacts of ocean disposal of fish wastes are listed as 1) high oxygen demand on receiving waters, 2) visible surface slick, 3) turbidity plume, 4) organic enrichment, 5) the attractant of undesirable predator species (i.e., sharks).

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of nutrients; artificial attractant to biological organisms.

Chang, B.D., and C.D. Levings. 1976. Laboratory experiments on the effects of ocean dumping on benthic invertebrates II. Effects of burial on the heart cockle (Clinocardium nuttallii) and the Dungeness crab (Cancer magister). Dept. Env. Fish. Mar. Ser. Res. Dev. Tech. Rept. 662. 23 pp. (ADF&G, Habitat Library, #B0822.)

Burial experiments with two types of solid wastes (dredge spoil [sand], wood chips) were performed in the laboratory using the heart cockle and the Dungeness crab. Cockles buried with 20 cm of sand or wood chips were immobilized after 24 h, whereas animals buried shallower moved upwards to establish siphon contact with water. After burial by sand, crabs tried to establish a clear opening through the sand to the buccal cavity using respiratory currents. This was not observed when crabs were buried over 5 cm deep. When possible, crabs moved upwards through sand and established contact with water. Movement was accomplished by pushing up on the walking legs. Twenty cm of sand prevented upward movement and led to the death of immobilized crabs after 5 d. (Author's abstract)

Activity: solid waste disposal.

Impact: addition of substrate materials.

Chapman, G.A. 1978. Toxicities of cadmium, copper, and zinc to four juvenile stages of chinook salmon and steelhead. Trans. Am. Fish. Soc. 107(6): 841-847. (ADF&G, Habitat Library, #R3858.)

Continuous-flow toxicity tests were conducted under laboratory conditions to determine the relative tolerance of newly hatched alevins, swim-up alevins, parr (5 to 8 mo old), and smolts of chinook salmon (Orcorhynchus tshawytscha) and steelhead (Salmo gairdneri) to cadmium, copper and zinc. Newly hatched alevins were much more tolerant to cadmium and, to a lesser extent, to zinc than were later (more mature) juvenile forms. However, the later progression from swim-up alevin, through parr, to smolt was accompanied by a slight increase in metal tolerance. The 96-h LC_{50} values (concentrations killing 50% of the testfish in 96 h) for all four life stages ranged from 1.0 to greater than 27 ug cadmium/l, 17 to 38 ug copper/l, and 93 to 815 ug zinc/l. Steelhead were consistently more sensitive to these metals than were chinook.

Regardless of the species or life stage used in toxicity tests, acute mortality data are seldom used directly for estimating safe levels of chemicals in natural waters because chronic toxic effects usually occur at levels well below those that are acutely lethal. However, acute mortality data from metals are often utilized in estimating safe levels in fresh water; in these instances, the 96-h LC_{50} values are multiplied by a fractional application factor. The report, Water Quality Criteria, July 1976, by the U.S. Environmental Protection Agency recommends that safe levels of copper and zinc be estimated by multiplying the 96-h LC_{50} of sensitive species by the application factors 0.1 and 0.01, respectively.

Activity: processing minerals; solid waste disposal.

Impact: change in levels of heavy metals.

Chapman, D.W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Trans. Am. Fish. Soc. 109:357-363. (ADF&G, Habitat Library, #R3005.)

Salmonid habitat and biomass were examined in 50-70-m pairs of altered and control sections of small (discharges less than 0.3 m^3/sec) streams around Puget Sound in western Washington in 1978-1979. Altered sections had been channelized or used by livestock. Channelization significantly reduced overhead cover, sinuosity, wetted area, and woody bank cover while increasing bank grasses. Total habitat area declined in altered sections. These impacts most damaged the quality of habitat for cutthroat trout over 70 mm in length. The biomass of coho salmon did not decline significantly in altered sections except in area severely damaged. Zero-age trout (cutthroat and steelhead) suffered no loss of habitat quality, although larger trout did, except in areas of severe physical impact. Short-term effects of machinery operation in the one stream for which data were obtained included biomass depletions of all species and size classes. Channelization and livestock use appeared to reduce the quality of winter habitat for salmonids. In altered sections with stable bottoms, no recent damage history, relatively little silt and sand, and adequate riffle areas, the reduction in overhead cover appeared to lead to higher standing crops of salmonids, suggesting that fish production in many streams of the Puget Sound area may be light-limited. (Author's abstract: modified)

Activity: channelizing waterways; grazing.

Impact: change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

Chasse, C. 1981. Les dimensions spaciales et temporelles de la perturbation de l'ecosysteme littoral par le petrole de l'Amoco Cadiz. Lecons et propositions. (Spacial and temporal pertebations of the littoral ecosystem by Amoco Cadiz oil: lessons and propositions). In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France. (ADF&G, Habitat Library, #R4325.)

A total quantitative evaluation of the ecological damage is necessary. No species seems to have disappeared. A practical methodological model is given. Since the oil spill of the Torrey Canyon, it has been known that petroleum pollution may profoundly modify the ecological equilibrium. To study the effect of the Amoco Cadiz oil on the Brittany coast, a quantitative study of the population decrease in rockface intertidal molluscs was performed at 135 different sites. There was a definite fluctuation in the population of herbivorous shelled gastropods (Littorina and Gibbula) that corresponds to the degree of oil contamination. The seasonal changes studied during 20 mo in 10 sites were considered in order to restitute the original impact. The BIGHORN index of the stress undergone by the fauna was thus obtained for the 300 km of coast studied.

The initial biomass losses of the areas of the 75 classes from intertidal and subtidal habitats have been totaled for each of the 135 polluted coastal districts. The total initial loss comes to 26,000 metric tons of dry organic matter with standard deviation +/- 4,900 metric tons. But a necrological balance is not an ecological balance. Though some of the populations are increasing, serious effects are still occuring. Other species that survived the first year are now showing large mortalities.

The following conclusions were reached:

- High toxicity effects due to emulsified oil in the total water column can be shown by mapping.
- A permanent reference control of the biomass is required.

Note: article in French, but tables and figures useful. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Choate, J.S. 1972. Effects of stream channeling on wetlands in a Missesota watershed. J. Wildl. Manage., 36(3):940-944. (ADF&G, Habitat Library, #R5094.)

Over 60 m of stream was channeled in the lower three-quarters of the Hawk Creek watershed, west-central Minnesota. The channels permitted more rapid removal of flood waters but also encouraged construction of ditches and tiles by providing improved outlets. Wetlands valuable to waterfowl and other wildlife were drained. As a result, the loss of habitat included the complete drainage of a 300-acre lake. On a percentage basis, wetland loss in the lower part of the watershed was nine times greater than in the unchanneled upper quartter. (Author's abstract: modified)

Activity: channelizing waterways; draining.

Impact: change in depth or velocity of water.

Chutter, F.M. 1969. The effects of silt and sand or the invertebrate fauna of streams and rivers. Hy. 34:57-77. (ADF&G, Habitat Library, #R5095.)

Most of the literature concerned with the effects of silt and sand on the invertebrate fauna of streams and rivers has described changes taking place when biotopes are completely smothered by silt and sand. Few of these studies recorded the kinds of animals found. There have been few studies of the effect of silt and sand on individual species. The invertebrate fauna of two biotypes in the streams and rivers of the Vaal River system, South Africa, changed with the amount of silt and sand in the watercourses. Where there were large amounts of silt and sand the variety of animals recorded from the stones in current biotopes was reduced, but the density of the fauna as a whole did not change. However, the density of many groups of animals was affected. Some of the animals affected by silt and sand appeared in larger numbers below impoundments in which silt and sand would settle. In the sediment biotopes, the summer density of the fauna was lowest where there was a lot of silt and sand. Large amounts of silt and sand were associated with large summer declines in the surface-dwelling animals as a proportion of the whole sediment fauna. Differences between the summer proportions of surface-dwelling forms in fine and coarse sediments were due to faunal differences. Sediments were not studied below impoundments.

It is concluded that there may be considerable changes in the composition of the stones in current fauna due to silt and sand without the biotope being smothered and that increase in the amount of silt and sand in river beds lead to increased instability of the sediments, which adversely affects their fauna. (Author's summary)

Activity: channelizing waterways; clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Ciliberti, V.A. 1980. The Libby Dam project: an expost facto analysis of selected environmental impacts, mitigation commitments, recreation usage and hydroelectric power production. Montana Water Resources Research Center Res. Rept. No. 106. Montana State Univ., Bozeman. (ADF&G, Habitat Library, #B6269.)

Environmental impacts cuased by the Libby Dam project in northwest Montana have been considerable. Mitigation of the loss of big-game winter range will be difficult. Cause and effect relationships of impacts and mitigation on the river below the dam are difficult to evaluate. Adverse impacts included increased suspended sediment discharge, mitrogen supersaturation, and changed regimen of the river stage and discharge. The more moderated temperature regime, however, was favorable to fish populations.

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen.

Clarke, R.McV. 1974. The effects of effluents from metal mines on aquatic ecosystems in Canada. A literature review. Fish. Mar. Serv. Res. Dev. Tech. Rep. 488. 150 pp. (ADF&G, Habitat Library, #B5058.)

Metal mine effluents are a complex of components, including metals, sulphur compounds, and organic reagents, many of which may have deleterious effects on aquatic ecosystems. Information on the toxicity of 47 components or groups of components is reviewed. Twenty-four of 26 components for which data were available were present in the effluent from at least one Canadian metal mine at concentrations that are potentially lethal to aquatic organisms. Despite many factors, such as pH, temperature, and hardness, affecting the toxicity of mine effluent components, effluents from 9 of the 11 mines for which data were available were lethal to fishes in 96 h or less. The major toxicants in the lethal effluents were considered to be heavy metals, arsenic, suspended solids, pH, or cyanide. Changes in levels of suspended solids and siltation, heavy metals, total dissolved solids, pH, hardness, sulphate or arsenic were the major chemical changes in water receiving discharged mine effluents. The aquatic biota were adversely affected by the discharge of mine effluents at 19 of 22 localities; fish communities were reduced or altered at 8 localities; and the plankton community was altered at 1 locality. Productivity was decreased at one locality, and this was inferred at another locality. (Author's abstract: modified.)

Activity: processing minerals.

Impact: change in turbidity or suspended sediments; change in levels of pH, alkalinity, or hardness; change in levels of heavy metals; change in levels of chlorinated compounds.

Clarke, R.McV., D.G. Alexander, R.W. Boychuk, B.S.C. Chu, and H.D. Maciorowski. 1977. The effect of chlorination on the acute lethal toxicity of Winnipeg municipal wastes. Fish. Mar. Serv. Tech. Rept. 712: 16 pp. (ADF&G, Habitat Library, #B6232.)

Chlorination increased the acute lethal toxicity of Winnipeg municipal wastes to fish and aquatic invertebrates under laboratory conditions and to caged black bullheads (Ictalurus melas) in the Red River. The acute lethal toxicity increased with the total residual chlorine concentration, which increased with the chlorine dose. At chlorine doses of 6-8 mg/l, which are necessary to meet the proposed total coliform requirement of less than 1,500 Most Probable Number/100 ml in the effluent, the 96-h LC50s for rainbow trout were 3.5-7-5% chlorinated municipal wastes, but the laboratory 96-h LC50s underestimated the acute lethal toxicity of chlorinated municipal wastes. From studies in other laboratories it is projected that chlorination of Winnipeg municipal wastes at 6-8 mg/l could affect the life cycles of fish and aquatic invertebrates at concentrations as low as 0.03% chlorinated municipal wastes. The discharge of municipal wastes chlorinated at 6-8 mg/l could create a fishless zone in the Red River extending at least 0.52 km downstream of the outfall and could affect the feeding and spawning movements of fish populations in the Red River. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Clewell, A., L. Garney, D. Harlos, and E. Tobi. 1976. Biological effects of fill-roads across salt marshes. Dept. Biol. Sci., Florida State Univ., Tallahassee. 16 pp. (ADF&G, Habitat Library, #B5976.)

This study was designed to determine the biological and environmental effects of the presence of fill-roads built across tidal salt marshes in the Northern Gulf Coast of Florida. Seven sites within five marshes were studied. At each site, vegetational zonation was determined, densities of three species of molluscs (<u>Littorina irrorata</u>, <u>Cerithidea scalariformis</u>, and <u>Melampus bidentatus</u>) were determined, and salinities and elevations above mean sea level were measured. Data revealed, in some cases, that environmental modification could be attributed to the presence of solid-fill roads. The authors conclusions included the following: 1) if tidal flow is unaffected by the presence of the structure, the marsh will not be affected, except where the road was constructed; 2) if tidal sheet flow is severely restricted, saltwater mollusc populations will be destroyed within days or weeks and salt-intolerant plants will invade within 4 yr; 3) ditching causes faster drainage than is normal in saltwater marsh at low tide. Vegetational zonation and animal distribution were unaffected by such rapid drainage, but the size of fish and aquatic invertebrate populations may be positively affected.

Activity: filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; change in level of salinity; introduction or removal of species.

Collodi, P., M.S. Stekoll, and S.D. Rice. 1984. Hepatic aryl hydrocarbon hydroxylase activities in coho salmon (Oncorpynchus kisutch) exposed to petroleum hydrocarbons. Comp. Biochem. Physiol. 79(2):337-341. (ADF&G, Habitat Library, #R3681.)

Coho salmon exposed to the water-soluble fraction (WSF) of Cook Inlet crude oil for a maximum of 30 d showed a greater than three-fold increase in hepatic aryl hydrocarbon hydroxylase (AHH) activity. The initial increase in enzyme activity appeared between 2 and 5 d of exposure and increased as a function of increased exposure time. Persistence of the induced enzyme activity was dependent on the length and the concentration of WSF exposure. Handling stress had no effect on the AHH activity, but starvation caused a decrease in the activity. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Conan, G., and M. Friha. 1981. Effets des pollutions par les hydrocarbures du petrlier Amoco Cadiz sur la croissance des soles et des plies dans l'estuaire de l'Aber Benoit. (Effects of hydrocarbon pollution from Amoco Cadiz oil on the growth of sole and plaice in the Aber Benoit estuary). In Amoco Cadiz, Fates and efects of the oil spill. Proceedings international symposium, Centre Oceanologique de Bretagne, Brest, France. (ADF&G, Habitat Library, #R4324.)

The growth in standard length and otolith length of plaice and sole caught in the Aber Benoit estuary (Northern Brittany) were estimated over a series of 2-6 yr preceeding the Amoco Cadiz wreck. Growth assessments were made by reading and measuring annual rings and microrings on otoliths of fishes caught 1 yr after the oil spill. The Aber Benoit, an estuarine area, was severely impacted by the spill in 1978. Hydrocarbons from the Amoco Cadiz were still abundant in the sediments in November 1979. The growth of plaices (Pleuronectes platessa) and soles (Solea vulgaris) of all captured age groups was significantly lower during 1978 than during the previous years. After the spill, the growth rates progressively slowed down over a 1 yr period. No sharp inhibition of growth over a short time lapse was evidenced. For soles, average annual size increments were more severely reduced for younger age groups (25% of normal) than for older age groups (88%). A reverse pattern was observed for plaices; younger age groups were less affected (88% of normal annual size increments) than older ones (30% of normal annual size increment). The animals from Aber Benoit were significantly slimmer than control individuals captured in places away from the oil spill. Up to 80% of soles and plaices captured in the Aber Benoit had fin and tail rot 9 mo after the wreckage. This proportion progressively dropped to about 10% over the next 11 mo.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Congdon, J.C. 1971. Fish populations of channelized and unchannelized sections of the Chariton River, Missouri. In E. Schneberger and J.L. Funk, eds. Stream channelization: a symposium. Special Publ. No. 2. North Central Division, Am. Fish. Soc., Omaha, Nebraska. (ADF&G, Habitat Library, #R5120.)

early 100% of the 1,842 mi of major streams north of the Missouri River have been channelized or are threatened with channelization or inundation by flood control reservoirs. The objective of this study was to determine fisheries losses resulting from stream channelization.

Mark and recapture population estimates using electrofishing gear and rotenone were made to determine standing crops and species composition of fish populations in channelized and unchannelized sections of the Chariton River, Missouri.

In the unchannelized section 21 species of fish were found compared to 13 species in the channelized section. The standing crop of fish in the unchannelized section was estimated to be 304 lb/acre compared to 53 lb/acre in the channelized section, an 83% reduction. In the unchannelized section, carp (152 lb/acre), river carpsuckers (77 lb/acre), and channel catfish (44 lb/acre) were the dominant species. In the channelized section channel catfish (31 lb/acre), river carpsuckers (14 lb/acre), and carp (5 lb/acre), were the dominant species.

The standing crop of catchable-size fish in the unchannelized section was estimated to be 187 lb/acre compared to 27 lb/acre in the channelized section, a 86% reduction. There were six species of catchable-size fish in the unchannelized section compared to four in the channelized section.

Channel straightening resulted in the loss of 103 mi of river, or a 55.2% reduction in stream length. The combined effects of a poorer environment and reduced stream length resulted in an estimated 87.0% reduction in total standing crop in the studied channelized section. The standing crop of catchable-size fish was reduced by 89%. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; introduction or removal of species.

Cooper, C.O., and T.A. Wesche. 1976. Stream channel modification to enhance trout habitat under low flow conditions. Water Res. Inst., Office of Water Res. Tech., Rept. Series No. 58., Washington, D.C. 107 pp. (ADF&G, Habitat Library, #B1825.)

The traditional impetus for stream improvement for fisheries has centered around restoring channels that have been physically abused by the activities of man (road construction, mining, livestock grazing, etc.) in the presence of an ample water supply. In an increasing number of situations in the Rocky Mountain region, the fishery problems associated with low natural flows are compounded by diversion for municipal, agricultrual, or other uses.

Based on water depths and velocities required for various phases of the trout life cycle, channel modification to constrict and consolidate low flows and thereby increase trout habitat in Douglas Creek was carried out in the summer of 1974.

Artificial overhangs and low-profile gabion structures were found to be effective, easy to install, strong enough to withstand high discharge, and fairly inexpensive.

The effects of the modification on the fishery cannot be quantified without several more years of evaluation; however, trout were found using the artificial overhangs and in the vicinity of all other structures. (Author's abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats); grading/plowing; grazing; processing minerals.

Impact: change in depth or velocity of water; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - diversions.

Corbett, E.S., Lynch, J.A., and W.E. Sopper. 1978. Timber harvesting practices and water quality in the eastern United States. J. For. 76(8):484-488. (ADF&G, Habitat Library, #R3845.)

Data from forested experimental watersheds in the eastern United States indicate that leaching of nutrients after timber harvesting, especially clear-cutting, tends to increase from south to north, while increases in streamwater temperature and sediment loadings tend to decrease. Concentrations of nutrients in streamwater are highest where revegetation of cutover areas is delayed. Also, increased streamwater temperature (in addition to increased light) caused by exposing stream channels may influence water quality be affecting a wide range of physical, chemical, and biological processes. Soil erosion losses from harvesting operations can be kept to acceptable levels by following available land-management guidelines and with supervision by qualified foresters. Buffer strips, in which only light selection cutting is allowed, will help minimize sedimentation as well as nutrient leaching and stream temperature increases. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; change in levels of nutrients.

Cordone, A.J., and D.W. Kelly. 1961. The influences of inorganic sediment on the aquatic life of streams. Cal. Fish and Game 47(2):189-228. (ADF&G, Habitat Library, #R3563.)

This report is a review of investigations made of the effects of inorganic sediment on the aquatic life of streams. The literature studied to date allows two conclusions: 1) that sediment is harmful to trout and salmon streams; and 2) much damage to streams from sedimentation can be prevented with known land use methods. An extensive bibliography documents early literature on sedimentation in aquatic stream environments.

Activity: channelizing waterways; clearing and tree harvest; dredging; filling (aquatic and wetland habitats); grading/plowing; grazing; stream crossing - fords.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Cote, R.P. 1976. The effects of petroleum refinery liquid wastes on aquatic life, with special emphasis on the Canadian environment. National Research Council of Canada, N.R.C. Associate Committee on Scientific Criteria for Environmental Quality, Ottawa, Canada. Publication No. 15021 of the Environmental Secretariat. 78 pp. (ADF&G, Habitat Library, #B0628.)

This report assesses the impact of petroleum refinery waterborne wastes on aquatic ecosystems. In Canada, there are specific petroleum refineries whose effluents are highly toxic to fish; however, the majority of refinery effluents tend to be moderately or not acutely lethal. In many cases, petroleum refineries do not contribute large volumes of waste-waters to the environment, and there is a continuing trend towards a reduction in effluent volume.

Some of the major effluent components are known to be highly toxic under certain circumstances. One of the difficulties in assessment is that the toxic components are discharged in complex mixtures that can contain phenols, sulfides, heavy metals, etc., and that vary according to specific refinery operations.

Rifinery operations may create and discharge carcinogenic compounds, cumulative toxicants, and compounds that can affect the sensory perception of aquatic organisms, in addition to affecting the taste and odor of fish flesh.

Since refinery effluents are generally discharged into areas already receiving one or more wastes, it is not always possible to determine and assess the specific effects of refinery effluents on the environment under actual field conditions. It then becomes important to conduct toxico-pharmacological studies, in order to diagnose effects in the environment that are relatable to specific causes. (Author's summary)

(Note: This report deals exclusively with Petroleum Refinery waterborne wastes and does not include the topic of oil spills from tankers, etc.).

Activity: processing oil/gas.

Impact: change in levels of heavy metals; change in levels of other toxic compounds - sulfurous compounds; change in levels of other toxic compounds - other; change in levels of hydrocarbons.

Coutant, C.C. 1976. Thermal effects: literature review. J. Water Pollut. Control Fed. 48(6):1,486-1,544. (ADF&G, Habitat Library, #R4877.)

Coutant listed 605 references pertaining to thermal effects on freshwater and anadromous fish and invertebrates and reviewed them in the following categories: site studies, effects on growth and production, community responses, reproduction, development, morphology, distribution, thermal tolerance, oxygen metabolism, growth, feeding activity and digestion, temperature and other stresses, preferred temperature, activity, predator prey relations, decomposers, diseases and parasites, and beneficial uses. Specific information presented by the author is too extensive to summarize in this volume.

Activity: grading/plowing; processing geothermal energy; processing lumber/kraft/pulp; processing minerals; processing oil/gas; sewage disposal.

Impact: change in water temperature; change in level of dissolved oxygen, nitrogen.

Cowan, C.A., and M.W. Oswood. 1983. Input and storage of benthic detritus in an Alaskan subarctic stream. Polar Biol. 2:35-40. (ADF&G, Habitat Library, #R5144.)

Allochthonous leaf litter input and storage of benthic detritus were measured in Monument Creek, a second-order interior Alaskan stream. Litter input was very low, totaling 62.5 g ash-free dry weight (AFDW) m^2/yr in 1980. Peak input coincided with autumnal leaf fall. Benthic detritus storage was similarly low. CPOM (coarse particulate organic matter, > 1 mm) ranged from 2.8 to 18.9 g AFDW/M^2, peaking in mid September. MPOM (medium particulate organic matter, 250 um - 1 mm) ranged from 3.7 to 10.9 g AFDW .m^{-2}, peaking in May. SPOM (small particulate organic matter, 80-250 um) ranged from 2.0 to 9.0 g AFDW .m^{-2} and also peaked in May. Compared to streams in temperate regions, Monument Creek is receiving and storing less energy from the surrounding forest.

This does not, however, necessarily diminish the relative importance of the detritus pathway in subarctic streams. Cold water temperatures, short "growing seasons," and prolonged ice cover may be restrictive to autochthonous production as well. Productive capacities (e.g., fish production) of high-latitude streams may be fundamentally limited by low allochthonous input. (Author's summary)

Activity: channelizing waterways; clearing and tree harvest; grading/plowing; grazing; processing minerals.

Impact: alteration of natural cover - riparian vegetation.

Cowen, I.M. 1974. Some environmental considerations in the planning, construction and maintenance of northern roads with relevance to the Mackenzie Valley Highway. Prepared for Environment Advisory Council (additional source information unknown) 58 pp. (ADF&G, Habitat Library, #R3216.)

This document provides a verions of considerations pertaining to planning, construction, and maintenance of roads in northern regions. It is primarily useful in identifying problems that are of particular concern or unique to cold environments. Topics pertinent to the planning phase include designation of purpose, biological factors, chemical pollutants, physical destruction to fish passage and impacts to wildlife. A helpful section is devoted to considerations involved in constructing roads to accommodate aesthetic interests rather than simply to transport people and materials. Topics included under construction and maintenance activities include road alignment, clearing of right-of-way, disposal of debris, cuts and fills, disposal of spoils, borrow pits, revegetation practices, and route selection.

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; addition of physical barriers - partial obstructions.

Craig, P.C. 1985. Aquatic survey of the Kaktovik dredging operation, 1983 and 1984. Rept. by LGL Alaska Research Associates for North Slope Borough. 25 pp. (ADF&G, Habitat Library, #B6255.)

During the summers of 1983 and 1984, the North Slope Borough dredged for gravel in a small embayment adjacent to Barter Island on the Beaufort Sea coastline. Survey results indicated that turbidity and suspended sediment levels in this embayment were generally within the range of naturally occurring levels of these variables except in the immediate vicinity of the stockpile outflow. There was no apparent avoidance or attraction to dredging operations by arctic char or arctic cisco, but fourhorn sculpin were most abundant in the highly turbid waters of the stockpile outflow.

Activity: dredging.

Impact: change in turbidity or suspended sediments; addition of substrate materials; artificial attractant to biological organisms.

Craig, P.C., and W.B. Griffiths. 1981. Passage of large fish around a causeway in Prudhoe Bay, Alaska. Arctic 34(4):314-317. (ADF&G, Habitat Library, #R3874.)

Craig and Griffiths studied fish movement around a 2.8 km solid-fill causeway in Prudhoe Bay by tagging anadromous least and arctic cisco on each side of the causeway in summer. Tagging data indicated that the causeway, which resembled naturally occurring barrier islands, did not impede fish movement. The causeway did change the local environment; water temperatures were 2-4°C cooler and salinities 10 ppt higher on the west side.

The authors noted that if more causeways were added, each structure could alter the nearshore temperature/salinity regimes, and the cumulative effect of these changes could be significant to fish in brackish coastal waters. Longer causeways or causeways joining offshore barrier islands might effect the coastal migration of anadromous fish. This study examined only highly mobile fish greater than 200 mm in length; movements of small anadromous fish have not been studied. (See Johnson 1984 for subsequent study involving this causeway.)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; addition of physical barriers - partial obstructions; change in level of salinity.

Cronin, L.E., G. Gunter, and S.H. Hopkins. 1971. Effects of engineering activities on coastal ecology. Dept. of Army, Corps of Eng., Off. of Chief Eng. 25 pp. (ADF&G, Habitat Library, #R3843.)

This report presents a listing of pertinent Army Corps of Engineers activities, with analyses and evaluations of the ecological effects. Thirteen types of engineering activity were evaluated in this report in relation to the effects they have on coastal ecology. These activities include dredging, filling, dams, levees and spillways, diversions, jetties and groins, beach nourishment, land-cut canals, weed control, hurricane barriers, finger-type developments, oceanic water disposal, and wetlands modification. The authors provide a general description of the environmental problems associated with these activities, as well as identifying problems that lack research information.

Activity: dredging; filling (aquatic and wetland habitats); solid waste disposal; water regulation/withdrawal/irrigation.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; addition of physical barriers - impoundments; addition of physical barriers - diversions; addition of physical barriers - partial obstructions; change in level of salinity.

Crothers, J.H. 1983. Field experiments on the effects of crude oil and dispersant on the common animal and plants of rocky sea shores. Mar. Environ. Res. 8:215-239. (ADF&G, Habitat Library, #R3188.)

In experiments of the coast of Great Britain, Forties Field crude oil and BP 1100WD dispersant were sprayed on to small areas of the rocky shore over a period of several days to simulate conditions following an oil spill. Detailed observations were made at monthly intervals of marked 0-1 mi^2 quadrats within (and without) the treated areas. Some areas received oil only, others dispersant only, and the third set received oil followed by dispersant.

The experiments included two parts, one to simulate a July incident and the other a January incident.

In these experiments of repeated pollution of small areas on rocky sea shores, it was shown that a) the effect on seaweed-covered shores was minimal; b) recovery from all treatments was rapid, in that any species eliminated soon recolonized; but c) some long-term effects on barnacle density were becoming apparent after a year or so.

BP 1100WD, in the concentration applied, was not significantly toxic to the rocky shore organisms and certainly less undesirable than Forties Field crude oil. Sites receiving a combination of oil and dispersant were most seriously affected. Recovery from winter treatments was slightly slower than in summer.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Crouse, M.R., C.A. Callahan, K.W. Malueg, and S.E. Dominguez. 1981. Effects of fine sediments on growth of juvenile coho salmon in laboratory streams. Trans. Am. Fish. Soc. 110:281-286. (ADF&G, Habitat Library, #R5080.)

Juvenile coho salmon (Oncorhynchus kisutch) production (tissue elaboration) was monitored in 12 laboratory streams under six replicate treatment levels of fine sedimentation. Increasing sedimentation suppressed fish production. Our data confirm that habitats of salmonid juveniles, as well as spawning areas, should be protected against fine sediments. Substrate Score, a visual technique for evaluating stream substrate quality, correlated closely with both the geometric mean particle size of the substrate and fish production and can be easily applied in the field. (Authors abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

Culp, J.M., and R.W. Davies. 1983. An assessment of the effects of streambank clear-cutting on macroinvertebrate communities in a managed watershed. Can. Tech. Rept. Fish. Aquat. Sci. No. 1208. 115 pp. (ADF&G, Habitat Library, #B1933.)

Three macroinvertebrate sampling sites were established on Carnation Creek, Vancouver Island, British Columbia, and sampled from 1974-1980 to determine the effects of logging, with or without buffer zones, on macroinvertebrate communities. Logging without a buffer zone increased streambank erosion and the resulting sedimentation of streambank material caused a significant increase in the proportion of less than 9 mm sediment particles in the substrate. Although logging opened the forest canopy and increased the light available for primary production, algal biomass did not increase after logging because phosphorus remained the limiting factor. Allochthonous litter input to the stream was significantly reduced at both logged sites, but the site with a buffer zone provided greater amounts of leaf litter to the stream and had a higher postlogging benthic standing crop than the site without a buffer zone.

Throughout the pre- and postlogging periods, seasonal changes in macro-invertebrate community composition were strongly affected by the seasonality of discharge: high (winter), low (summer), and transitional (spring and fall). Trophic composition of the macroinvertebrate communities was not affected by logging, with collectors, collector-scrapers, and collector-predators numerically dominant during all seasons and years. Logging of the streambank significantly decreased macroinvertebrate densities in the winters, primarily because postlogging sedimentation increased winter scouring. Macroinvertebrate densities at the site without a buffer zone were also reduced in the summer and transitional periods because of sediment intrusion into the substrate and the reduced standing crop of detritus. Macroinvertebrate communities were less detrimentally affected by logging when a less-than-10-m-wide riparian buffer zone and natural debris dams were left along the stream. The buffer zone reduced logging-related scouring in the winter, and leaf litter input in the summer and transitional period was more similar to prelogging conditions.

Experimental manipulations of substrate particle size and detritus quality and quantity were conducted in the field, which established that detritus quality and quantity is more important in determining macroinvertebrate distribution and abundance than substrate particle size. The responses to detritus varied between macroinvertebrate taxa and even among members of the same trophic guild.

Sediment-addition experiments were conducted to determine the effect of downstream movement of fine sediments by saltation on macroinvertebrate drift and benthic density. Saltation of sediments increased drift rates and decreased benthic densities, with the timing and pattern of the drift increases being related to the vertical distribution of macroinvertebrates in the substrate.

Because the streambank of coastal streams provides important energy subsidies to macroinvertebrate communities and mediates sediment input to the stream, logging of the streambank is detrimental to macroinvertebrates. Management guidelines must protect the streambank interface with the forest if coastal streams are to be maintained as productive salmon fry rearing habitat. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation.

Cummins, L.K. 1985. The effect that dragging log-lead angle has on site disturbance and productivity. Pages 75-79 in Improving mountain logging planning, techniques, and hardware. Proceedings IUFRO and 6th Pacific NW Skyline Logging Symposium. Vancouver, BC. (ADF&G, Habitat Library, #R5089.)

Research literature shows no definitive data to ecologically support skyline systems using partial suspension. It does show that site disturbance from logs plowing the soil provides physical properties more conducive to site productivity. Research on skyline log-lead angles and a new equation for yarding forces show that the compactive compression force on the ground is greater from the dragging end of a partially suspended log. Present and future economic benefits and site productivity are directly related to the cable-harvesting method. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments.

Czyzewska, K. 1976. The effect of detergents on larval development of crab. Mar. Pollut. Bull. 7(6):108-112. (ADF&G, Habitat Library, #R3857.)

In this laboratory study, the effect of a mixture of anionic (ethoxylate) and nonionic (alkylate) detergents on developmental stages of the crab Rhithropanopeus from final embryogenesis to the melgalopa larval stage was studied. Larval resistance increased with age. Larvae still in the eggshells were only slightly sensitive because of the thick and impermeable chorion. Low concentrations of detergents exerted a favorable effect, causing a decrease in larval morality, but during molts there was an increasing mortality and a lengthening of the developmental period of the larvae. A toxic effect of detergents manifested itself as an increased mortality rate, a reduction of the average lifetime of larvae, and as changes in the physiological standard of these organisms' behavior.

Activity: drilling; processing lumber/kraft/pulp; sewage disposal; transport of oil/gas/water - water.

Impact: change in levels of other toxic compounds - other.

Dane, B.G. 1978a. Culvert guidelines: recommendations for the design and installation of culverts in British Columbia to avoid conflict with anadromous fish. Fish. Mar. Serv. Tech. Rept. No. 811: 57 pp. (ADF&G, Habitat Library, #B1924.)

This report examines the hydraulic criteria that should be satisfied at a culvert installation to ensure that fish can migrate through the facility with a minimum of stress. The report also outlines guidelines that, if incorporated into the culvert design, should produce a facility that will permit the free passage of fish in most situations. The design of auxiliary fish passage structures such as culvert baffles and tailwater control facil- ities are discussed and illustrated by drawings. Consideration is also given to the installation of culverts to avoid conflicts with fish use in the stream both during and after the construction period. Guidance is also given concerning the procedures to follow for necessary approval of a proposed culvert installation by the Fisheries and Marine Service. (Author's abstract)

Activity: stream crossing - structures.

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Dane, B.G. 1978b. A review and resolution of fish passage problems at culverts sites in British Columbia. Fisheries and Marine Service, Pacific Region, Dept. Fisheries and Environment, Resource Service Branch, Vancouver, B.C. Tech. Rept. No. 810. 126 pp. (ADF&G, Habitat Library, #B5356.)

Culverts can have a major impact upon anadromous fish populations by impeding or preventing upstream migration. Often, a culvert may determine the extent of fish utilization in a stream, and, in an extreme situation, the presence of a culvert could exclude all anadromous fish from a particular watershed. The success or failure of a fish in migrating through a culvert depends upon the swimming ability of the fish and the hydraulic conditions present at the site. In general, culverts represent a streamlined, hydraulically efficient flow channel in which velocities are maximized and usually constant throughout most of the culvert length. This feature is in stark contrast to a natural stream channel, which provides an endless variety of landscapes throughout its length and width, thus offering the fish a choice of routes that are suited to its swimming ability.

Through experimentation and observation, the swimming abilities of salmon and steelhead trout have been documented. Thus, it is possible to determine the hydraulic criteria that must be satisfied at the site to ensure that free fish passage is maintained. However, as a delay of as little as one day can have serious consequences for spawning fish, it is important that the appropriate hydraulic criteria be maintained at the site throughout the spawning migration period. This would normally require that detailed streamflow records in the form of a hydrograph be studied and compared with the fish migration period to determine the maximum and minimum discharges upon which to base fish passage design. However, because of the lack of detailed streamflow records for many small stream, it is impractical to apply concise standards to fish passage design in most situations, and a more general system must be used.

This publication also includes specific information (in appendices) regarding the swimming performance of fish (with an emphasis on salmonids) and of factors such as size of fish, temperature, fatigue, illumination, injury and disease, and pollution that effect their swimming performance. Also included are fish-passage requirements for stream-flow velocities and guidelines for culvert design and installation.

Activity: stream crossing - structures.

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Darnell, R.M., W.E. Pequegnat, B.M. James, F.J. Benson, and R.A. Defenbaugh. 1976. Impacts of construction activities in wetlands of the United States. EPA-600/3-76-045. U.S. Environmental Protection Agency, Corvallis, Ore. 393 pp. (ADF&G, Habitat Library, #B0863.)

Included in the primary types of construction activity which severely impact United States wetlands are bank and shoreline construction and dredging and channelization. Each type of construction activity is attended by an identifiable suite of physical and chemical alterations of the wetland environment that may extend for many miles from the site of construction and that may persist for many years. In turn, each type of chemical or physical modification has been shown to induce a derived set of biological effects, many of which are predictable, in general, if not in specific detail. The most environmentally damaging effects of construction activities in wetland areas, in order of importance, are direct habitat loss, addition of suspended solids, and modification of water levels and flow regimes. Major construction-related impacts derive also from altered water temperatures, pH, nutrient levels, oxygen, carbon dioxide, and pollutants such as heavy metals and biocides. The first 75 pages of the report constitute an introduction to the ecology of wetlands. (Annotation from Stearn and Stearn 1980b)

Activity: channelizing waterways; dredging; filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness; change in levels of biocides.

Dauble, D.D., S.A. Barraclough, R.M. Bean, and W.E. Fallon. 1983. Chronic effects of coal-liquification dispersions on fathead minnows and rainbow trout. Trans. Am. Fish. Soc. 112(5):712-719. (ADF&G, Habitat Library, #R3870.)

Under laboratory conditions, partial-life-cycle bioassays were conducted on fathead minnows (Pimephales promela) and rainbow trout (Salmo gairdneri). Tests were done under continuous-flow regimes, with water-soluble fractions (WSF) derived from a coal liquid, which was a 2.9:1 blend of middle to heavy distillate produced by the solvent-refined coal (SRC-II) process. Phenols constituted 95% of the organic carbon in the WSFs. Growth of larval fathead minnows was significantly reduced at 0.25 mg/l total phenols as determined by dye photometry. Spawning of adult fathead minnows exposed to coal-liquid WSFs was inhibited at 1.27 mg/l total phenols and was significantly reduced at 0.62 mg/l total phenols. Spawning inhibition was not permanent at concentrations tested. After 21 d of exposure, fathead minnow pairs resumed spawning upon transfer to control water. The minimal concentration of WSF that resulted in significant mortality of rainbow trout embryos was timedependent. No rainbow trout embryos survived 14 d of exposure to greater than or equal 2.98 mg/l total phenols because of egg mortality or premature hatching. Swim-up rainbow trout suffered rapid mortality after 28 d exposure to 0.13 mg/l total phenols: death was partially attributable to clogging of their gills by fungal growth. Long-term toxic effects of complex organic mixtures may not be predictable, based on dilution of known constituents, because changes in the composition of water-soluble components occur because of chemical and biological degradation.

Activity: processing oil/gas.

Impact: change in levels of hydrocarbons.

Davis, W.P., and D.P. Middaugh. 1975. A revised review of the impact of chlorination processes upon marine organisms: update 1977. Chapter 15 in R.L. Jolley, ed. Water chlorination, environmental impact and health effects. Vol. 1. Proceedings of the conference on the environmental impact of water chlorination, Oak Ridge, TM, Oct. 22-24, 1975. Ann Arbor, Michigan: Ann Arbor Science Publishers. (ADF&G, Habitat Library, #R3971.)

This paper presents a theoretical degradation model of chlorine added to marine waters. Additionally, it summarizes literature reporting laboratory or ecological effects of chlorination. It is revised to attempt incorporationn of pertinent literature through 1977.

For over 175 yr, chlorine gas has been used in industrial, biocidal and disinfection applications. The chemistry of chlorine in fresh water is relatively well known, but long-range effects on the organisms and the ecological communities of marine waters have barely been studied. Until recently, the so-called "chlorine demand" of treated or receiving waters has been considered a desirable feature that assured degradation of actively oxidizing states of chlorine to a nontoxic state. With continuing and increased use of chlorine as an antifouling biocide in powerplants and as a disinfectant of municipal wastes, concern has arisen that resulting by-products, such as induced halogenated hydrocarbons, could potentially reach environmentally harmful levels. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Day, C.G., and K.L. Carvell. 1979. Effects of power line corridor clearance and maintenance on stream habitat. Pages 383-385 in Strategies for protection and management of floodplain wetlands and other riparian ecosystems. USDA: Forest Service, Gen. Tech. Rept. WO-12. (ADF&G, Habitat Library, #R3578.)

Investigations were initiated to determine the effects of power line corridor clearing and maintenance on streams. The principal procedures of this study consisted of vegetation mapping, physical measurements of the study streams, and streambank erosion observations. Particular emphasis was placed on summer diurnal temperature regimes, specifically peak temperature rises.

It is apparent from this work that the environmental changes resulting from power line corridor clearance and maintenance activities can have adverse effects on stream habitat.

Small-to-medium-sized streams were the most sensitive to environmental changes and most vulnerable to landscape manipulation, especially with the removal of protective riparian vegetation. When surrounding and overhanging vegetation was maintained in the riparian zone bordering small streams, the normal longitudinal temperature gradient rise remained unaltered. Larger streams remain "summer cool" regardless of right-of-way exposure.

Under clear sky conditions, maximum stream temperatures occurred about 1500-1600 hours.

Activity: stream crossing - fords;transport personnel/equipment/material - land.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation.

Daye, P.G. 1980. Effects of abmient pH on fish: an annotated bibliography. Can. Tech. Rept. Fish. Aquat. Sci. 950. 28 pp. (ADF&G, Habitat Library, #B1347.)

An annotated bibliography on the effects of ambient pH on fish, consisting of 316 citations, is presented in alphabetical sequence according to author. These references are also cross-indexed by subject and geographical listings. (Author's abstract)

Activity: processing minerals.

Impact: change in levels of pH, alkalinity, or hardness.

DeGange, A.R., and T.C. Newby. 1980. Mortality of seabirds and fish in a lost salmon drift net. Mar. Pollut. Bull. 11(11):322-323. (ADF&G, Habitat Library, #R3871.)

The authors of this paper primarily address seabird mortality that is the result of birds entanglement in lost or discarded fish nesting. Losses of fish species are presented, but estimates of the magnitude of loss of fish life is not quantitatively addressed. The authors simply state that in 1978 they recovered two salmon sharks, one ragfish, and over 200 chum and silver salmon from a lost salmon drift net in the western North Pacific and that these observations indicate that such nets may be a hazard to marine fish for extended periods of time. Millions of seabirds reportedly have died in the North Pacific Ocean from entanglement in commercial fish nets since the inception of the Japanese offshore salmon drift net fishery in 1952. Annual net-related mortality in the Pacific region is estimated at 215,000 to 715,000 birds. The Danish fishery, which has been the only other large offshore salmon drift net fishery in the Northern Hemisphere in recent years (1965-1975), reportedly killed 500,000 (± 250,000) thick-billed murres annually.

Although mortality of marine life in lost or discarded fish netting is not generally considered a significant problem from a population stand point, the authors believe that such waste of marine resources could be easily prevented with more care on the part of fishermen. The authors cite a trip they completed aboard a Japanese training vessel in August 1978 when a 3,500-m drift net was found afloat in the North Pacific. The 6-m deep net was estimated (by condition of entangled animals and the algae growth on the netting) to have been afloat for 30 d or more. In the 1,500 m of netting that was lifted by the crew, 75 fresh salmon, approximately 150 rotten salmon, and 99 seabirds were entangled. Short-tailed shearwaters were the predominant bird in the catch, which included six species of birds.

Activity: netting.

Impact: impingement or entrainment or entanglement.

DeGraeve, G.M. 1982. Avoidance response of rainbow trout to phenol. Prog. Fish Cult. 44(2):82-86. (ADF&G, Habitat Library, #R4226.)

An eight-concentration intermittent-flow proportional diluter was modified to provide continuous flow to four separate avoidance chambers and used to test the avoidance response to phenol of rainbow trout (Salmo gairdneri) in three separate 5 d tests. When single fish had been acclimated for 24 h, a flow of phenol was initiated on one side of each avoidance chamber and well water was started on the other. After 48 h the phenol and well water sides were switched, and the experiment was continued for another 48 h; the positions of the fish in the chambers were monitored photographically throughout the test. Results of tests with 12 rainbow trout indicated that the threshold avoidance level was between 6.5 and 3.2 mg/l phenol, which was between 58 and 73% of the phenol 96-h LC_{50} for rainbow trout. Because long-term effects for rainbow trout exposed to phenol have been documented at concentrations as low as 0.2 mg/l, the avoidance tests were not nearly as sensitive as toxicity tests with embryos and larvae. (Author's abstract)

Activity: filling (aquatic and wetland habitats); processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Decker-Hess, J. and S.L. McMullin. 1983. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Ann. prog. rept. Montana Dept. of Fish, Wildlife, and Parks. Fisheries Research and Special Projects Bureau. Kalispell. 172 pp. (ADF&G, Habitat Library, #B1123.)

The operation of Kerr Dam, located below Flathead Lake, Montana, during 1982 and 1983 was found to have significant impacts on shoreline embryo survival of kokanee above the minimum pool level regardless of ambient air temperatures. The dam operation of drawing down the reservior and at an average monthly rate of 0.55 m through February and holding the pool near minimum until spring refill is not conducive to successful shoreline embryo survival.

Major impacts from the 1982 and 1983 operation of the dam on kokanee embryo survival included loss of optimum incubating gravels, mortality resulting from desiccation, and a delay in embryo development. Intragravel dissolved oxygen levels appeared to play the most critical role in survival of redds constructed below minimum pool. Lowest rates of survival were found in areas where the oxygen level was less than 5.0 mg/l. As gravels became exposed by lake drawdown, ambient air temperatures significantly affected their development. Cooler gravel temperatures delayed development, and development could be reduced by 1 mo in exposed gravels. An experimental egg plant showed a negative correlation between survival and length of exposure by lake drawdown.

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water; change in level of dissolved oxygen, nitrogen.

Department of the Environment and Department of Fisheries and Oceans. 1983. A rationale for standards relating to the discharge of sediments into Yukon streams from placer mines. Environ. Can., Environ. Prot. Serv., Dept. Fish. and Oceans, New Westminster, B.C., Canada. 24 pp. (ADF&G, Habitat Library, #B2556.)

This report includes a concise review of selected literature related to the adverse effects of sediments on instream primary producers, stream inverte- brates and fish. In addition, it includes a section on sediment discharge standards for streams in the Yukon Territory. Sediment discharge standards are presented for five classes of streams. Stream classes are leased on biological senitivities and past mining activity in each waterbody. Recommended maximum discharge levels of suspended solids for Class A, B and C, D and E streams are 0.0 mg/l, 100 mg/l, 100 or 1,000 mg/l, depending upon drainage pattern, and 1,000 mg/l, respectively.

Activity: channelizing waterways; dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments.

Desaunay, Y. 1981. Evolution des stocks de poissons plats dans la zone contaminee par l'Amoco Cadiz. (Changes in flat fish stocks in the zone contaminated by the Amoco Cadiz.) In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France. (ADF&G, Habitat Library, #R4329.)

Three species of fish (plaice, sole, and dob) were studied between April 1978 and October 1979 in the bays of Morlaix and Lannion. The impacts of pollution included a lack of recruitment in 1978, reduced growth (primarily of plaice), and physical abnormalities (fin erosion, bent fin rays). After 18 months, the 1979 recruitment seems to be satisfactory. These effects will be seen at least until the end of 1981. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Didiuk, A., D.G. Wright. 1975. The effect of a drilling waste on the survival and emergence of the chironomid Chironomus tentans (Fabricius). Fish. Mar. Serv. Res. Dev. Tech. Rept. 586. 18 pp. (ADF&G, Habitat Library, #B6238.)

The environmental impact of the disposal of waste drilling fluids in northern Canada is poorly understood. Laboratory studies were conducted to assess the effects of deposition of thin (1, 3, and 7 mm) layers of drilling wastes on the survival of larvae of the chironomid Chironomus tentans (Fabricius), using the emergence of adults as an index of survival. An average of 84% of the organisms emerged as adults from control tanks. Populations treated with 1-mm, 3-mm, or 7-mm layers of drilling wastes achieved only 61, 47. of 12% emergence, respectively.

The creation of a physical barrier to construction of burrows and perturbation of feeding mechanisms are postulated as the reasons for the decreased rates of emergence. The creation of a physical barrier to construction of burrows and perturbation of feeding mechanisms are postulated as the reasons for the decreased rates of emergence. It is recommended that the disposal of drilling wastes in fresh water should be avoided. (Author's abstract)

Activity: drilling.

Impact: addition of substrate materials.

Dodge, W.E., E.E. Possardt, R.J. Reed, and W.P. MacConnell. 1976. Channelization assessment, White River, Vermont: remote sensing, benthos, and wildlife. USDI: USFWS. FWS/OBS-76/07. 73 pp. (ADF&G, Habitat Library, #B1733.)

Following torrential flooding in the Shite River, Vermont, watershed in June 1973, much stream and riparian habitat was altered to alleviate future flood threats to roads, bridges, and private properties. Remote sensing, using aerial photogrammetic techniques, was used to develop a database for the stream, bank, vegetation, and land-use characteristics of the watershed. Aerial photographs indicated that 7% of the streams were channelized. Benthic organism sampling revealed no significant differences (P greater than 0.05) between channelized and nonchannelezed areas after 8 mo, probably because of the rapid recolonization by the benthos. Thirty-three, 27.38, and 46% of all songbirds collected by mist-netting during the fall 1974, spring 1975, and early and later summer 1975, respectively, were from channelized areas. Species diversity was greater in nonchannelized areas, for all four sampling periods. Swallows and spotted sandpipers (Actitis macularia) were more abundant in channelized areas while thrushes, vireos, and particularly the warblers were more abundant in nonchannelized areas. Twenty-eight, 39, and 39% of all small mammals collected by live trapping during fall 1974, early summer, and late summer 1975 sampling periods, respectively, were from channelized areas. Shrews and jumping mice were the most adversely affected small mammals; the white-footed mouse (Persomyscus leucopus), the most abundant small mammal, recovered rapidly in the channelized areas. No gross differences were observed between channelized and control (nonchannelized) sites for the furbearers and amphibians. The most drastic impact on wildlife occurred at channelized sites where streamside vegetation was the most extensively destroyed. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water.

Drinkwater, K.F. 1979. Flow in the Strait of Canso and St. Georges Bay, Nova Scotia. Pages 12-18 in F.D. McCracken, ed. Canso marine environment workshop. Part 4 of 4 parts. Physical oceanography and environmental effects. Fish. Mar. Serv. Tech. Rept. No. 834. 81 pp. (ADF&G, Habitat Library, #R3816.)

The Strait of Canso is the narrow body of water separating Cape Breton Island from the Nova Scotia mainland. A causeway across the strait was begun in September 1952 and was completed in the fall of 1954. Prior to completion the strait connected St. Georges Bay to the north with Chedabucto Bay to the south. The author utilizes a number of existing databases to provide an analysis of the changes in physical oceanographic characteristics due to construction of the causeway.

A difference in mean sea level between St. Georges Bay and Chedabucto Bay drove a residual southerly current through the strait prior to completion of the causeway. Mean sea level difference at the causeway upon completion was between 0.09 and 0.20 m. The temperature and salinity structure of St. Georges Bay did not appear to change with the presence of the causeway, except in the vicinity immediately north of the construction site. The residence time of water in St. Georges Bay is approximately 2 to 4 weeks and did not change significantly with completion of the causeway. Residual currents in the bay likely underwent a change with completion of the causeway. The largest changes are expected to have occurred near the strait, while the magnitude of the change would decrease with distance from the strait. It is expected that only small changes in flow occurred north of St. Georges Bay.

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in level of salinity.

Dryden, R.L., and J.N. Stein. 1975. Guidelines for the protection of the fish resources of the Northwest Territories during highway construction and operation. Dept. of the Env., Fisheries and Marine Service, Tech. Rept. Series No. CEN/T-75-1. 32 pp. (ADF&G, Habitat Library, #B1710.)

Based on the results of fisheries investigations conducted between 1971 and 1974, guidelines have been designed to protect the fish resources of the Districts of Keewatin and Mackenzie, as well as Baffin and Southampton islands, from major disruptions resulting from the construction and operation of highway and road systems. These guidelines are not intended to serve as regulations but merely as an aid in meeting Fisheries and Marine Service requirements, as defined by the Fisheries Act of Canada.

Culvert average cross-sectional velocities must not exceed 0.9 m/s (3 fps) when fish passage is a requirement, unless it can be satisfactorily demonstrated that the culvert design includes a selected region wherein velocities are low enough to permit fish passage. This selected region must be continuous throughout the culvert length and of sufficient size to permit the fish to locate it and to swim through it. Alternatives such as baffles should be considered when these velocity criteria cannot be met through regular design procedures. The minimum desirable water level within culverts during periods of fish movement should be 20.3 cm (8 in).

In general, no in-stream construction activity should be attempted from May 1 to June 30 and from September 1 to November 15, as these periods are considered critical to fish migrations and spawning. However, these dates vary slightly with geographical spread and variations in the timing of freeze-up and breakup. The spring or fall restrictions may be lifted if it can be satisfactorily demonstrated that fish-spawning activities do not occur during either or both of these periods in the stream under consideration.

Three days is considered the maximum time period during which the blockage to annual spawning migrations can be tolerated without causing serious disruption to the spawning cycle. During this 3-d period, the above-mentioned velocity criteria need not be adhered to. Variables such as the timing of fish migration and the timing and duration of peak flows will determine when this 3-d delay limitation should be in effect.

The removal of stream gravel may seriously damage spawning habitat and therefore should not be attempted without first determining the spawning potential of the area in question and consulting with Fisheries and Marine Service. Highway routing should avoid close proximity or paralleling of streams or water bodies and should cross river systems as far upstream from the river mouth or as far downstream from a lake outlet as possible.

Specific restrictions, other than those discussed within these guidelines, may have to be imposed where unique fish species or life history aspects are involved. Conversely, the guidelines may be tempered upon consideration of species composition or the individual characteristics of a stream system. (Authors' abstract)

Activity: clearing and tree harvest; grading/plowing; stream crossing - structures.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of physical barriers - diversions; addition of physical barriers - partial obstructions.

Duba, G.A. 1981. Storm-sewer input of heavy metals into an urban lake environment. Ph.D. Thesis, Western Michigan Univ., Kalamazoo. 117 pp. (ADF&G, Habitat Library, #B6275.)

The author measured the concentration of lead, cadmium, zinc, and copper in runoff entering an urban lake in East Grand Rapids, Michigan. Samples were collected of stormwater, substrate, aquatic macrophytes, chironomid larvae, snails, and fish. Results showed that the metals did not show hgihest concentrations at highest trophic levels. Lead, zinc, and copper were detected in the stormwater. Some substrate was highly contaminated. Benthic organisms contained high metal levels but do not seem to be passing the metals along the food chain in a form that is available for absorption by other organisms. Fish contained low levels of metals and were safe for human consumption.

Activity: sewage disposal.

Impact: change in levels of heavy metals.

Dunn, B.P., and J. Fee. 1979. Polycyclic aromatic hydrocarbon carcinogens in commercial seafoods. J. Fish. Res. Bd. Can. 36: 1469-1476. (ADF&G, Habitat Library, #R3878.)

The authors examined 22 species of fresh and processed commercial seafoods, from 15 countries, for presence of polycyclic aromatic hydrocarbon (PAH) carcinogens. PAH carcinogens are released from creosote-treated wood, which is often used for construction of piers, pilings, and wharfs.

Fresh and processed commercial seafoods were analysed for the PAH benzo-(a)pyrene using a thin-layer chromatographic separation technique and quantitation by flourescence. Vertebrate fish samples did not contain detectable levels. Levels in most shellfish samples were generally less than 10 ng/g wet weight, but occasional samples contained up to 36 ng/g. Crab and shrimp samples contained little or no benzo(a)pyrene (nd to 0.5 ng/g). Commercial lobsters contained 0.8 to 7.9 ng/g. The source of contamination of lobsters was further investigated, utilizing high pressure liquid chromatography to measure 13 PAH isomers. Freshly caught lobsters had less than 1 ng/g benzo-(a)pyrene. Lobsters that had been kept in a commercial tidal pound constructed of creosoted timber contained highly elevated levels of benzo(a)pyrene and other carcinogenic hydrocarbons, including chrysene, benzo(a)anthracene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. The maximum level of benzo(a)pyrene was 2300 ng/g wet weight in digestive gland and 281 ng/g in edible tail meat. These levels are substantially higher than previously reported for any foodstuff and are most probably attributable to creosote contamination during impoundment. (Authors abstract: modified)

Activity: filling (aquatic and wetland habitats).

Impact: change in levels of other toxic compounds - other; change in levels of hydrocarbons.

Dunn, B.P., and D.R. Young. 1976. Baseline levels of benzo(a)pyrene in Southern California mussels. Mar. Pollut. Bull. 7(12):231-234. (ADF&G, Habitat Library, #R0327.)

Petroleum hydrocarbons enter the marine environment from many sources. Contamination of productive coastal waters is a major concern in areas where industrial and urban sources of hydrocarbons are apparent. Particularly, the carcinogen, benzo(a)pyrene (BAP), has been increasingly predominant in marine organisms. The authors examined the intertidal mussel, Mytilus, for baseline BAP levels. Mussel samples were collected from mainland and island stations situated throughout the Southern California Bight. Mytilus californianus was sampled where it was found; otherwise, M. edulis was sampled. Samples were collected whenever possible at locations at least 1 km from the nearest pier or wharf. In some cases, however, only mussels growing directly in pilings could be obtained.

Results of the study indicate that even in a heavily populated coastal area, baseline levels of BAP in mussel in locations removed from local sources of pollution are at or near the limits of detectability (0.1 ug/kg). The only samples that had elevated levels of BAP were those in which the mussels were growing directly on creosoted pilings or were growing near large harbours or marinas (up to 8.2 ug/kg).

Activity: processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Duval, W.A., R.D. Volkmar, W.I. Specht, and F.W. Johnson. 1976. Environmental impact of stream channelization. Water Res. Bull. 12:799-812. (ADF&G, Habitat Library, #R5096.)

Geologic, engineering, and biological investigations of six Pennsylvania cold-water streams were undertaken to determine the impact of channel modifications instituted both prior to and following Hurricane Agnes. The primary focus of the study was on the ecological changes brought about by stream channelization.

No long-term deleterious effects on water quality, attached algae, benthic fauna, or forage fish populations were found. Trout, however, were found to be in greater numbers and weight in natural than in channelized stream reaches. Lack of suitable physical habitat appears to be the primary cause of reduced trout populations in stream reaches that have been channelized. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water.

Duval, W.S., ESL Environmental Sciences Ltd., and F.F. Slaney and Co., Ltd. 1980. A review of the impacts of log handling on coastal marine environments and resources. Prepared for Council of Forest Industries/Government Estuary, Foreshore, and Water Log Handling and Transportation Study. 224 pp. (ADF&G, Habitat Library, #B6252.)

This is a very extensive report that summarizes the results of several different studies on the impacts of log handling on the marine environment and compares the impacts resulting from different log-handling techniques. Topics covered include methods of log handling, physical and chemical impacts of log handling, impacts of log handling on plant communities, benthic and intertidal invertebrates, and fish. The report also includes a bibliography with key words.

The physical and chemical impacts of log handling depend primarily on the location and areal extent of the operation, the volume and species of logs handled, the activities occurring at the site, and particularly the local current patterns and intensity. The impacts of all phases of log handling are greater when activities affect intertidal areas. The most significant effect of log dumping is the accumulation of bark and wood debris on nearby bottom sediments. Other significant impacts of log dumping include substrate scouring or compaction and loss of logs through sinkage, and secondary or subsequent impacts are chemical and associated with hydrogen sulfide release, increased BOD during decomposition of accumulated bark and wood, and the release of wood leachates, which also exert an oxygen demand.

Activity: log storage/transport.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates; change in levels of other toxic compounds - sulfurous compounds.

Dwyer, W.P. and R.H. Kramer. 1975. The influence of temperature on scope for activity in cutthroat trout, *Salmo clarki*. Trans. Am. Fish. Soc. 104(3):552-554.

Metabolism in fish is usually measured by the rate of oxygen consumption, either in a state of zero activity (standard metabolic rate) or under conditions of continuous forced activity (active metabolic rate). One hundred eleven active and 71 standard metabolic rate estimates were made on 90-g cutthroat trout *Salmo clarki* at five temperatures. Active metabolism was lowest at 5°C (363 mg O_2/kg-h) and highest at 15°C (597 mg O_2/kg-h). At 20°C and 24°C it was 559 and 491 mg/kg-h, respectively. Scope for activity ranged from a low of 316 mg O_2/kg-h at 5°C to a high of 486 mg O_2/kg-h at 15°C then down to 374 mg O_2/kg-h at 24°C. Standard metabolisms at 5, 10, 15, 20, and 24°C were 47, 73, 111, 129, and 117 mg O_2/kg-h, respectively. These data suggest that the cutthroat trout studied would be expected to have greater survival if stocked at 15°C rather than at the other test temperatures, provided that the limiting factor is as discussed. However, other environmental factors may often times override any physiological advantage from stocking at water temperatures where scope for activity is greatest.

Activity: sewage disposal; water regulation/withdrawal/irrigation.

Impact: change in water temperature.

Eagle, R.A., P.A. Hardiman, M.G. Norton, and R.S. Nunny. 1978. The field assessment of effects of dumping wastes at sea: 3. a survey of the sewage sludge disposal area in Lyme Bay. Fish. Res. Tech. Rept. No. 49. Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research, Lowestoft, England. 22 pp. (ADF&G, Habitat Library, #B6216.)

The survey of the ara in Lyme Bay used for the dumping of sewage sludge containing treated sewage and heavy metals shows dispersion processes to be ineffective in preventing accumulations of dumped material in the sediments. Despite the small quantity of sludge dumped (62,000 m^3/yr), levels of carbon, nitrogen, and trace metals such as mercury, copper, zinc, lead, nickel, and chromium are significantly elevated in the area most commonly used for dumping.

The three variables, number of species, density and diversity were evenly distributed relative to sediment type (i.e., were not correlated). However, the number of species per sample was significantly, negatively correlated with sediment organic content in the sand and silt/clay fractions, with abundance of coliforms and with the levels of zinc and mercury. These five variables are statistically independent, but their distributions are determined by a single factor - the dumping of sewage sludge. As well as being independent of sediment type, these correlations were not related to the station clusters, some samples from each of the clusters having significantly lower numbers of species. Using ordination techniques, it was shown that the species composition was uniform throughout the area and that all the common species were evenly distributed (coefficent of variation less than 1.0). The correlation of number of species to tracers of the dumped sewage sludge was therefore due to a reduction in the number of rarer species present near the dumping ground. The reduction in number of species was about 10%, but the mechanism of the impoverishment is unknown. This was the only detected effect of sludge dumping in Lyme Bay. (Author's conclusions)

Activity: solid waste disposal.

Impact: addition of substrate materials; change in levels of heavy metals; change in levels of nutrients.

Eagle, R.A., P.A. Hardiman, M.G. Norton, R.S. Nunny, and M.S. Rolfe. 1979. The field assessment of effects of dumping wastes at sea:5. The disposal of solid wastes off the northeast coast of England. Fish. Res. Tech. Rept. No. 51. Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research, Lowestoft, England. 34 pp. (ADF&G, Habitat Library, #B6218.)

Surveys have allowed the distribution of dumped colliery waste and fly ash to be determined in an area extending from south of the Wear dumping ground to north of the Blyth dumping ground.

The primary areas affected by waste dumping are those where deposition of the waste occurs immedialy after dumping. These are found, in most cases, inshore of the areas designated for dumping.

Although the waste reaches the sea bed very soon after dumping, subsequently some dispersion of a proportion of it takes place by movement in suspendsion and as bedload. Thus sediments surrounding the zones of active waste dumping also contain particles of waste origin. The most readily defined dispersion pathways for these wastes are those arising from the southward movement of sand-sized particles as bedload.

The effects of waste disposal on the benthos have been investigated in two of the four dumping areas. Fly ash and colliery waste dumping have caused severe depletion of the benthos (both in terms of species and abundance) in the areas where the waste is dumped with greatest intensity. There is evidence that some recovery has taken place on older and weathered waste deposits. Thus, the productivity of the areas currently affected could increase following a cessation in dumping.

Dumping has caused direct interference with commercial trawling and potting in the primary areas of waste dumping. The productivity of the fishery may have been reduced through depletion of the benthos in all areas and through the smothering of areas formerly suitable as crab and lobster habitat in the inshore zones of the Wear and Blyth dumping areas.

The area over which dumping has taken place (40 km^2) is more than three times the area licensed for dumping. The effect of dumping on fisheries has thus been greatly increased by dumping outside the licensed areas. (Author's conclusions)

Activity: solid waste disposal.

Impact: addition of substrate materials.

Ebel, W.J., H.L. Raymond, G.E. Monan, W.E. Farr, and G.K. Tanonaka. 1975. Effect of atmospheric gas supersaturation caused by dams on salmon and steelhead trout of the Snake and Columbia Rivers. USDC: NOAA, NMFS, Northwest Fisheries Center, Seattle, WA. 111 pp. (ADF&G, Habitat Library, #B6210.)

Dams constructed on the Columbia and Snake rivers have impounded most of the free flowing sections of these rivers and created a water condition that in high flow years is deadly to migrating salmon and steelhead trout. Several conclusions regarding the effect of supersaturation of atmospheric gas on fish in the Columbia River System are made from the laboratory and field data presented. The main conclusions reached are as follows:

1) Supersaturation of atmospheric gas has exceeded 130% over long stretches of the Columbia and Snake rivers during several years since 1968.

2) When either juvenile or adult salmonids are confined to shallow water (1 m), substantial mortality occurs at 115% Total Dissolved Gas (TDG) saturation after 25 d exposure.

3) When either juvenile or adult salmonids are allowed the option to sound and obtain hydrostatic compensation either in the laboratory or in the field, substantial mortality occurs when saturation levels (TDG) exceed 120% saturation after more than 20 d exposure.

4) On the basis of survival estimates made in the Snake River from 1966 to the present, we conclude that juvenile fish losses ranging from 40 to 95% do occur and a major portion of this mortality can be attributed to fish exposure to supersaturation of atmospheric gases during years of high flow.

5) Juvenile salmonids subjected to sublethal periods of exposure to super- saturation can recover when returned to normally saturated water, but adults do not recover and generally die from direct and indirect effects of the exposure to supersaturation. (Author's abstract)

Activity: water regulation/withdrawal/irrigation.

Impact: change in level of dissolved oxygen, nitrogen.

Edgell, M.C.R., and W.M. Ross. 1983. Marine log transportation and handling systems in British Columbia: Impacts on coastal management. Coastal Zone Manage. J. 11(1,2):41-69. (ADF&G, Habitat Library, #R3842.)

Over 90% of British Columbia's annual log harvest enters into complex water-based systems of transportation, storage, and handling. These systems have considerable impacts on a wide range of coastal resources and uses. A number of site-specific conflicts have arisen between forestry and preexisting or emerging values including fisheries, mariculture, recreational boating, and harbor redevelopment. Specific data on the impacts leading to conflict are often fragmentary. However, concerns about highly valued and fragile areas - particularly estuaries - along with industrial concerns regarding log losses and handling efficiency, have prompted changes in log handling. These include moves to dryland sorting, log bundling, and a redistribution of forestry activities in estuaries to accommodate other values. Conflict adjustments and responses have in the past been largely ad hoc and attempted in a jurisdictional vacuum concerning control of coastal management. A more inclusive strategy is now slowly emerging, which involves the coordinated participation of federal, provincial, and industrial interests. (Author's abstract)

Activity: log storage/transport.

Impact: physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates.

Edwards, C.J. 1977. The effects of channelization and mitigation on the fish community and population structure in the Olentangy River, Ohio. Ph.D. Thesis, Ohio State Univ. 161 pp. (ADF&G, Habitat Library, #B1164.)

Thirteen electrofishing surveys were completed during the period 1974-1976 on a channelized segment, a channelized segment with mitigation, and a natural segment of the Olentangy River, Ohio. Treatment of fish community and population data included chi-square analysis, contrasts among multinomial populations, calculated species diversity indices using numbers and biomass, fitness coefficients, and Page's nonparametric analysis of relative abundance, relative biomass, and the diversity indices. Results indicated that while certain populations were enhanced or unaffected, most were detrimentally affected by conventional channelization and channelization with mitigation when compared to the natural area of the river. The mitigated area maintained a community structure inferior to the natural area but was successful in ameliorating recovery and reducing losses when compared to the conventionally channeled area.

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water.

Edwards, R.R.C. 1978. Effects of water-soluble oil fractions on metabolism, growth, and carbon budget of the shrimp Crangon crangon. Mar. Biol. 46:259-265. (ADF&G, Habitat Library, #R3869.)

Juvenile shrimp, Crangon crangon L., were exposed to water-soluble crude oil fractions at 10, 15, and 20°C. During chronic exposure to oil fraction, a reduction in respiration and growth rate occurred that was related to strength of the extract. Mortality increased with strength of oil fraction and was highest at 20°C. Calculation of carbon budgets indicated that the extract reduced net carbon turnover at each temperature. Shrimp in oil extracts were hypersensitive to disturbance, with exaggerated escape reactions. This increased activity could increase changes of attack in the natural environment, thus reducing the shrimp's viability.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Edwards, C.J., B.L. Griswold, R.A. Tubb, E.C. Weber, and L.C. Woods. 1984. Mitigating effects of artificial riffles and pools on the fauna of a channelized warmwater stream. N. Am. J. Fish. Mgt., 4:194-203. (ADF&G, Habitat Library, #R5131.)

The effect of stream channelization on macroinvertebrates, fish, and the sport fishery was studied in the Olentangy River at Columbus, Ohio. Macroinvertebrate abundance, diversity indices, standing stock in the benthos, and drift were significantly lower in a channelized area than in either a natural area or a channelized area mitigated with artificial riffles and pools. Predominant macroinvertebrates were moving-water forms in the natural and mitigated areas and burrowing forms in the channelized areas. Diversity indices and relative abundance of game fish were nongame species became relatively abundant in the mitigated area when compared to the natural area. Composition of the sportfishing catch and catch rates accurately reflected the predominant fish community in each area. The biota in the area mitigated with artifical riffles and pools was similar to the biota in the natural area. (Author's abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; introduction or removal of species.

Elgershuizen, J.H.B.W. 1981. Some environmental impacts of a storm surge barrier. Mar. Pollut. Bull. 12:265-271. (ADF&G, Habitat Library, #R3868.)

The Dutch government closed an estuary with a storm-surge barrier instead of a dam to minimize ecological impacts, and the resulting changes in the local environment were noted. Sedimentation and resuspension may be influenced by changes in mixing and circulation patterns, erosion or enlargement of the salt marshes, and redistribution of the benthic communities. Red tide blooms, which fish avoid, may occur more heavily than before. The intertidal benthos, which provides food for fish, would be affected by changes in tidal frequency because the tide brings not only nutrients but also carries away feces. Shrimp and fish may be influenced by changes in their food spectrum. In addition, the storm-surge barrier may affect their migration rates because of a smaller exchange with the sea and the local higher water velocities at the mouth. The barrier may act as a threshold and could alter the capacity of the estuary as a nursery for fish. A stagnation period at the moment of shellfish/larvae swarming may affect the settling efficiency in the estuary.

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials; addition of physical barriers - partial obstructions; change in level of salinity; change in levels of nutrients.

Elliott, G.V. 1980. First interim report on the evaluation of stream crossings and effects of channel modifications on fishery resources along the route of the Trans-Alaska Pipiline. USDI: USFWS, Special Studies, Anchorage, AK. 77 pp. (ADF&G, Habitat Library, #B4362.)

During 1977, the effects of low water crossings and channel modification of streams were evaluated in five areas along the route of the Trans-Alaska Pipeline. The five areas included 1) Little Tonsina flats, 2) Gulkana River headwaters, 3) Million Dollar Creek 4) Pamlin's Potholes, and 5) Dietrich River. For each area, a general description of the fishery resource is provided, and the effects of constructing the pipeline are evaluated. At Little Tonsina flats the most obvious damage to fish habitat resulted from improper design of the work pad. No provision was made to allow blocked creeks to flow through the pad. In some instances, new stream channels were cut by the redirected flows. In other cases, severe sedimentation occurred from erosion of work pads during spring breakup. These effects were judged to be "long-lasting."

There appeared to be no barriers to fish passage at the Gulkana headwater sites, and the effects of stream channelization were unclear. It was noted that stream sedimentation and disruption of natural flows occurred in some cases, but the effects were not provided.

At Pamlin's Potholes area, several localities had barriers to fish passage that were attributable to construction activities. Discontinuous water flow during the winter occurred in Marsh Creek after the relatively compacted substrates of the natural channel were replaced with coarser and less compacted materials in channelized reaches. The newly placed materials allowed the water to flow through the gravel rather than on the surface. Other flow-related problems had to do with improper placement of culverts above the stream thalweg.

At Million Dollar Creek, the most obvious changes to fish habitat occurred in channelized reaches. Morphologically complex natural channels were replaced by a uniform channel. However, the author did not provide any information documentating the effect of these changes in fish.

Channelization in a headwater reach of the Dietrich River did not have any obvious harmful effects on fish and did not significantly alter the habitat. In its natural state, this reach of river is a fish gradient stream and has limited braiding. The channelized portion resulted in water velocities similar to natural velocities. During low flows in late summer, twice the density of juvenile grayling was captured in the channelized reaches as was captured in a similar natural reach.

Activity: channelizing waterways; stream crossing - fords.

Impact: change in depth or velocity of water; addition of substrate materials; addition of physical barriers - diversions.

Elliott, G.V. 1982. Final report on the evaluation of stream crossings and effects of channel modifications on fishery resources along the route of the trans-Alaska pipeline. USFWS. Special Studies: 1982. 110 pp. (ADF&G, Habitat Library, #B4365.)

This report is the second field report on the study designed to evaluate stream crossings and the effects of channel modifications on fishery resources along the route of the trans-Alaska oil pipeline. This report summarizes the fisheries use of several streams in the Atigun River drainage throughout the open-water season. The streams were impacted by construction of the Trans-Alaska Pipeline System (TAPS) work pad and low-water crossings used for drainage; burial of the pipeline within active floodplains; excavation of gravel material sites across or adjacent to active stream channels; and construction of the Yukon River to Prudhoe Bay haul road using culverts for drainage. In addition, the fisheries utilization of a variety of other streams in the Atigun, West Fork North Fork Chandalar, and Middle Fork Koyukuk River drainages was documented at various intervals throughout the open water season.

Two types of culverts of various sizes, round (CMP) and arch type (CMPA), were used as drainage structures for the four study streams crossed by the haul road. The culverts were set at slopes that were similar to the slopes of the natural stream channels in which they were placed. The culverts range from 62 to 104 ft in length. During the period of upstream fish movement, mean water velocity through these culverts were partial barriers to fish passage throughout most of the open-water season. The author cites recommended installation criteria that call for water velocities to be at or below fish swimming speeds through specified culvert lengths during a mean annual flood discharge. If these criteria had been followed during construction of the haul road, the existing culverts would not have been placed at any of the study streams. Rather, bridges, bottomless arch culverts, and oversized round or arch culverts buried below the stream channel bottom would have alleviated the problem of accelerating laminar flow through the length of a relatively smooth-bottomed culvert. The presence of natural substrate through the entire length of the structure would provide a more varied flow regime and improve fish passage.

The excavation of gravel material sites adversely impacted the fisheries of four study streams in several ways. The most severe impact was the loss of surface flow in three streams where gravel removal operations spanned the stream channel and in one stream where gravel removal operations were adjacent to the stream channel. The loss of surface flow occurred during the period of downstream emigration, blocking the passage of fish to over-wintering areas. The channelization through the respective material sites reduced the fish habitat value of several streams. The author points to the use of alternate sites in large river floodplains or in upland areas as a solution to the problems arising from gravel removal.

Burial of the hot oil pipeline within the active floodplain of the Atigun River headwaters adversely impacted the fish inhabiting this stream. Fall emigration of fish from this stream was blocked when surface flow was lost to the pipeline trench and/or thaw bulb. In addition, the artificial elevation of the temperature water reemerging from the pipeline thaw bulb was thought to adversely affect the fish population. The author recommends that burial of hot oil pipelines within active floodplains be avoided or that necessary mitigative measures be implemented to reduce thaw bulb expansion.

Activity: channelizing waterways; stream crossing - structures.

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Elliott, S.T. 1986. Ecology of rearing fish; a review report on Southeast Alaska findings. Fed. Aid in Fish Restoration and Anadromous Fish Studies. Proj. F-9-17, Job D-I-B. (ADF&G, Habitat Library, #B2019.)

A 1985 review of research findings from the Pacific Northwest on the environmental requirements of salmonids and the effects of timber harvest on salmonids are referenced to Southeast Alaska. Research strongly suggests that timber harvest in Southeast may increase sedimentation rates (reducing the egg-fry survival of salmonids) and that changes in watershed temperature regimes may have both positive and negative effects on nonrearing and rearing juveniles. Canopy removal increases primary productivity and, where nutrients are high, the number of age-0 fry can increase. Changes in stream flow, stability of stream habitat structures, and recruitment of woody debris necessary for habitat formation may eventually reduce rearing salmonid carrying capacity by as much as 50% over the long term. The magnitude of the effects vary among species with time and with the severity of the perturbations. Buffer zones are superior to other strategies in preserving stream productivity; methods are compared and discussed. (Author's abstract: modified)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; change in levels of nutrients.

Ellis, R.J. 1973. Preliminary biological survey of log-rafting and dumping areas in southeastern Alaska. NMFS Review 35(5/6):19-22. (ADF&G, Habitat Library, #R3827.)

Underwater observations by scuba divers were made to determine the amounts of bark, wood, and other debris on the bottom substrate at one marine log storage site and four log dump sites. In addition, the numbers of large invertebrates, such as crabs, snails, and sea anemones, were also qualatively assessed at each site. At the log storage site, the only apparent effect on fauna or flora was a marked decrease in abundance of plants (kelp and algae) directly under the rafts - possibly the result of shading. In contrast to the relatively minor effects at the storage site, log dump sites were characterized by a thick layer of silt, bark, twigs, and other debris that appeared to have accumulated over a period of years. Fauna and flora adjacent to these dump sites were nearly eliminated. (Author's abstract: partial)

Activity: log storage/transport.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in levels of other toxic compounds - bark or log leachates.

Elner, R.W., and S.L. Hamet. 1984. The effects of ocean dumping of dredge spoils onto juvenile lobster habitat: a field evaluation. Can. Tech. Rept. Fish. Aquatl. Sci. 1247. St. Andrews, N.B., Canada. 12 pp. (ADF&G, Habitat Library, #B1224.)

Two hundred cubic meters of noncontaminated sand-silt-clay sediment were dumped onto a presurveyed juvenile American lobster, Homarus americanus, habitat in Halifax Harbor, Nova Scotia. Scuba divers carried out five surveys of lobsters and crabs on the dump, the adjacent hard bottom, and on a control area over a 12-mo period. In addition, the divers charted the extensive changes in the topography of the dumped sediment and monitored the invasion of macrofauna and macroflora. Both lobster and crab densities on the dumped sediment remained low, relative to the adjacent hard bottom and the control area, over the postdump monitoring period. The few macrofaunal and macrofloral species invading the dump appeared either sedentary and constrained to settlement on exposed boulders above the spoil or were errant species. It was hypothesized that dumping can adversely affect lobsters and crabs by decreasing shelter and prey availability and, thus, increasing inter-and intraspecific competion. (Author's abstract)

Activity: solid waste disposal.

Impact: addition of substrate materials.

Elser, A. A. 1968. Fish populations of a trout stream in relation to major habitat zones and channel alterations. Trans. Am. Fish Soc. 97(4):389-397. (ADF&G, Habitat Library, #R5097.)

The relationship of fish populations to major habitat zones and channel alterations was studied in Little Prickly Pear Creek, Montana, during the summers of 1965 and 1966. Five major zones were defined as follows: headwater, meadow, mountain, lower meadow, and Wolf Creek Canyon, with at least one representative study section in each. Approximately 23% (6 of 30 mi) of the stream has been altered. Field measurements showed no pool-riffle periodicity in the altered mountain sections, while successive riffles were spaced at intervals of 5.7 widths in the unaltered areas. Altered sections of the mountain zone consisted, by area, of 87% shallow-fast with no deep-slow water, compared to 49 and 14%, respectively, for the unaltered sections. Amount of cover per acre of stream was about 80% greater in the unaltered mountain section than in the altered. Rock deflectors in the altered section of Wolf Creek Canyon rendered the physical characters of the stream nearly comparable to the unaltered sections. Fish populations were estimated by means of a simple mark-and-recapture census. Nontrout species were absent from the altered sections but made up 30 and 58% of the total number and weight, respectively, in the unaltered mountain sections. Trout were 78% more abundant in the unaltered mountain sections than in the altered, and a statistical test indicated a significant difference between the two trout populations. Standing crops of trout ranged from 40 to 226 lb/acre, and the total stream supported an estimated 20,400 trout greater than 4.0 in long weighting 9,500 lb. Channel alterations resulted in a total loss of 4,700 trout, with a total weight of 2,200 lb.

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; alteration of natural cover - riparian vegetation.

Emerson, J.W. 1971. Channelization: a case study. Science 173:325-326. (ADF&G, Habitat Library, #R5098.)

Channelization of the Blackwater River in Johnson County, Missouri, 60 yr ago nearly doubled the gradient, which caused an increase in the rate of erosion for the river and its tributaries. The present channel is wider and deeper than it was when newly dredged. Serious erosion problems were caused along stream banks, and there was much headward erosion of gullies leading to tributaries of the river. Most county bridges have been replaced or lengthened and have had vertical extensions added to the lower supports. In most cases the ends of the present bridges are threatened by bank erosion. Downstream reduction in channel capacity due to termination of dredging has caused channel sedimentation and increased flooding. (Annotation from Stearn and Stearn 1980b)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Erickson, S.J., and H.R. Foulk. 1980. Effects of continuous chlorination on entrained estuarine plankton. J. W. P. C. F. 52(1):44-47. (ADF&G, Habitat Library, #R3649.)

This report presents the results of the exposure of estuarine plankton present in flowing seawater aquaria to varying concentrations of sodium hypochlorite (NaOCl) to simulate constant chlorination. To estimate mortality, ATP from the plankton surviving chlorination was measured and compared as percent of control.

Aquaria systems were operated continuously for 1 yr, permitting examination of the effects of continuous chlorination at concentrations below those generally considered effective for the control of pathogens and fouling organisms. Temperature, salinity, and pH were dependent on natural conditions. Size of organisms allowed to enter, time of experiments, and chlorination were controlled. Chlorination reduced the microbial biomass of sea water at all concentrations tested.

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Erikson, D.E. 1984. Environmental monitoring study - Homer small boat harbor expansion - winter 1984. Dames and Moore, Anchorage, AK. 53 pp. + appendix. (ADF&G, Habitat Library, #B1789.)

This report presents data from preconstruction environmental monitoring field investigations and discusses the results. The purpose of this monitoring was to document and assess some key environmental conditions in the vicinity of the Seward Fisheries seafood waste outfall and the existing harbor entrance before construction modifications to the area occur. Sediment chemistry analyses were conducted on sediment samples collected from 19 locations around the outfall, as well as at a control area representing normal conditions and inside the harbor. The analyses indicated that the effect of the waste outfall on the quality of marine sediments has been relatively small to date. Sediment core samples were also analyzed for diversity and abundance of infauna near the seafood waste outfall. Epifauna were also examined for abundance and diversity. Two major groups of bottom organisms were described in the study area. The first group represents a species assemblage that was characteristic in bottom sediments that were undisturbed and showed a high level of abundance and diversity. The second group was located at the outfall site and was characterized by low species diversity and abundance. The most abundant organism in this group was a marine worm that is known to have a high tolerance of organically enriched sediments.

Water circulation and flow patterns were described within the harbor and related to transport and dispersal of seafood waste outfall. Conclusions of the study indicate that the proposed fill project will not adversely affect the dispersal of the seafood wastes. (Executive Summary: modified)

Activity: filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of substrate materials; addition of physical barriers - partial obstructions.

Erman, D.C., and D. Mahoney. 1983. Recovery after logging in streams with and without bufferstrips in northern California. California Water Resources Center, Univ. California, Contribution No. 186. 50 pp. (ADF&G, Habitat Library, #B6259.)

Streams with narrow buffer strips (less than 30 m) and without buffer strips in northern California were sampled 6-10 yr after logging and 5 or 6 yr after an initial postlogging study (see Erman et al. 1977) in order to evaluate recovery rates. Six narrow-buffered steams and six unbuffered streams were grouped in blocks with suitable unlogged (control) streams.

Unbuffered streams showed considerable but incomplete recovery based on a Shannon diversity index of macroinvertebrates. Compared to the mean of control streams the mean diversity of logged streams was 9.1% lower in 1980-81 compared to 25.2% lower in 1975. Narrow-buffered streams, by contrast, had changed little since the last survey. The mean diversity was 12.5% lower than controls in 1980 compared to 12.4% in 1975, and the six streams showed a positive association between buffer width and diversity index.

By employing a measure of transportable sediment stored in the stream bed the authors determined that the logged and narrow-buffered streams still contained significantly more fine sediment than comparable control streams.

Narrow buffers were not effective in promoting a more complete or rapid rate of recovery than streams without buffers. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: alteration of natural cover - riparian vegetation.

Erman, D.C., J.D. Newbold, and K.B. Roby. 1977. Evaluation of streamside bufferstrips for protecting aquatic organisms. California Water Resources Center, Univ. of California, Contribution No.165. 48 pp. (ADF&G, Habitat Library, #B6261.)

An evaluation of logging impacts on streams was based on an extensive survey during 1975 of 62 northern California streams. Streams had been logged without stream protection measures, had been logged with protective buffer strips, had been affected by localized disturbances (such as logging road stream crossings), and some were unaffected streams.

Benthic invertebrate communities of disturbed and undisturbed streams were compared by diversity index and ecological distance. Benthic invertebrate communities from streams logged without protective measures were significantly different from communities of unlogged (control) streams based on both diversity and ecological distance. Logging impacts were detected also in streams with buffer widths of less than approximately 30 m. Streams with bufferstrips wider than 30 m did not display logging impacts. There was a direct correlation between increases in an index of diversity and increases in buffer width, and hence probably the degree of stream protection increased with buffer widths up to 30 m.

Invertebrate communities of logged or disturbed streams had a lower diversity index and higher populations than unlogged streams. Increased populations were primarily in three taxa - Baetis, Nemoura, and Chironomidae.

Communities in localized disturbances were significantly different from control stream sections. The differences were qualitative (i.e., different taxa) and thus contrast with the differences noted in logged or narrow buffered streams.

Stream invertebrates were far more effective in discerning logging impacts than the physical and chemical parameters measured. Variation among watersheds and sampling error contributed to the failure of physical or chemical measures to detect logging impacts. Measurements of over 20 environmental variables from the streams are included and give an excellent catalogue of both disturbed and natural stream conditions in northern California. (Author's abstract)

This study was followed by additional work to determine the rate of recovery of buffered versus unbuffered reaches of waterways. See Erman and Mahoney (1983).

Activity: clearing and tree harvest.

Impact: alteration of natural cover - riparian vegetation.

Etnier, D.A. 1972. The effect of annual rechanneling on a stream fish population. Trans. Am. Fish. Soc. 101(2):372-375. (ADF&G, Habitat Library, #R5099.)

In 1967, as part of a flood control project bulldozers were used to widen and straighten the channel, smooth the banks, and create a uniform gradient in a tributary of the Little Pigion River near Sevierville, Tennessee. The channel is reworked each fall during low water to prevent the development of obstructions to the smooth flow of water. Prior to rechanneling, the stream was approximately 5 m in width and was comprised of pool/riffle habitats dominated by course gravel and boulder substrates. Several pools were nearly 1 m deep during low water. After channelizing occurred, the stream width at low water was widened to approximately 8 m; the pool/riffle sequence was replaced with a uniform gradient, with the substrate comprised entirely of medium gravel. The modified channel also had a relatively uniform depth, with an average mid-channel depth of about 15 cm. These changes in physical variables resulted in several changes in the aquatic biota. There was an obvious decrease in the abundance and diversity of benthic invertebrates. The abundance and diversity of mayflies, caddisflies, and stoneflies were markedly reduced (Ephemeroptera, Trichoptera, and Plecoptera, respectively), and some invertebrate taxa were entirely decimated (e.g., baetid, mayfly naiad (Isonychia spp.) and horsefly larva (Tabanus fairchildi). Similarly, there were obvious changes in the composition of the fish fauna. Of the three species of fish for which population estimates were available for pre- and post-channelizing periods, two species of darter (Etheostoma simoterum and E. stigmaeum) underwent drastic reductions in abundance while numbers of one species of hogsucker (Hypentelium nigricans) remained approximately the same. The author attributed the changes in the composition of the fish community to the instability of the gravel substrate, the overall decrease in diversity of physical habitat types, and the changes in the invertebrate community.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; physical disturbance of substrate materials; introduction or removal of species.

Evelyn T.P.T. 1972. A multispecies fish kill in Nanoose Harbor, B.C. September 29, 1971. Fish. Res. Bd. Can. Tech. Rept. No. 319. 14 pp. (ADF&G, Habitat Library, #B0779.)

On September 29, 1971, a fish kill occurred in Nanoose Harbor, British Columbia. A research team visited the site and observed moribund fish swimming on the surface, gasping in obvious distress, while shrimp and crabs gathered at the shoreline or congregated on rock outcrops close to the water's surface. All of the animals were readily caught by hand. Other animals (chiefly fish) had evidently been dead for many hours. Animals in the latter category were still in excellent condition. They were found on the beach where they had apparently been deposited during the dark hours by the previous high tide as it receded.

The cause of a multispecies fish kill was apparently a lack of dissolved oxygen. The oxygen shortage was brought about by the respiratory activity of a heavy and partly senescent plankton bloom (and its associated bacteria) that occurred during the dark in the shallow waters of the affected area.

Although this study is not directly related to a specific developmental activity, it is included here because of its conceptual relatedness to effects of entrophication caused by mans activities (e.g., sewage discharge).

Activity: sewage disposal.

Impact: change in level of dissolved oxygen, nitrogen; change in levels of nutrients.

Everest, F.H., and R.D. Harr. 1982. Silvicultural treatments. Vol. 6 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Series: 1979-. USDA: Forest Service. Pacific Northwest Forest and Range Experiment Station, Portland, OR. Gen. Tech. Rept. PNW-134. 19 pp. (ADF&G, Habitat Library, #B2439.)

Distribution of anadromous salmonids and coniferous forest coincides along much of the Pacific slope; consequently, the habitat of anadromous fish is subject to a wide variety of silvicultural treatments required to establish and nurture young forests. The silvicultural activities discussed in this paper are those necessary to rapidly establish and nurture young forest stands. These activities include 1) cutting prescriptions to improve natural regeneration, 2) broadcast burning to prepare site for planting or to reduce fire hazard, 3) mechanical site preparation to reduce logging residue and to prepare for reforestation, 4) seeding and planting, and 5) applying chemicals to selectively enhance growth of young trees.

Small streams suffer a greater risk of habitat degradation than large streams; and soils, climate, and geomorphology within a watershed generally determine the degree of risk. The risk of fish habitat degradation resulting from silvicultural treatments is linked to two primary factors: the potential for 1) increased or decreased water temperatures and 2) increased sedimentation.

Physical and climatic features within the range of anadromous salmonids cause a greatly elevated risk of damage in some geographic areas. For example, damage from decreased water temperatures can occur during cold winter weather where insulating streamside vegetation has been removed. High-risk areas are located in northern and central Idaho, northeastern Oregon, southeastern Washington, northern British Columbia, and Alaska.

Streams in mountainous areas with sedimentary or granitic soils that receive more than 120 cm annual precipitation or intense rainstorms (or rain or snow) and that produce both commercial timber and anadromous fish are most vulnerable to damage from sediment released by silvicultural activities. Fish habitat could be degraded by silvicultural treatments in other geographic areas, but the risk of damage is substantially lower.

Specific impacts to fish include a reduction in survival to emergence of fry due to the accumulation of fine sediments (less than 6.4 mm - diameter),in the gravel, an alteration of rearing potential due to shifts in the pool/riffle sequence of streams, a reduction in winter survival of fry due to a reduction in water temperature, and a loss of cover for fry from removal of riparian vegetation and accumulation of sediments in gravel interstices.

Activity: burning; chemical application; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; change in levels of biocides; change in levels of nutrients.

Falk, M.R., and M.J. Lawrence. 1973. Seismic exploration: its nature and effect on fish. Fisheries Operations Directorate, Resource Management Branch, Central Region, Winnipeg, Canada. Tech. Rept. Ser. No. CEN/T-73-9. 51 pp. (ADF&G, Habitat Library, #B5148.)

Seismic exploration in offshore and inland waterbodies of the Northwest Territories, Canada is evaluated in two parts. In the first part, literature pertaining to the nature and effect of explosive and nonexplosive seismic energy sources is presented. The second part is concerned with a study of the effects that seismic energy sources commonly used in the Northwest Territory have on fish. Caged arctic cisco (Coregonus autumnalis) and other small coregonids were subjected to the energy sources to determine their lethal characteristics. Aquaflex (a linear high explosive) detonated in 165-ft lengths on the bottom in 10 ft of water killed fish over an area of 36,200 ft^2. A 10-lb charge of 60% Geogel (a point high explosive) detonated 10 ft below the surface in 15 ft of water killed fish within an area of approximately 25,450 ft^2. In contrast, a 300 cubic inch Par Air Gun caused no direct fish mortalities.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Feder, H.M., and D.C. Burrell. 1982. Impact of seafood cannery waste on the benthic biota and adjacent waters of Dutch Harbor, Alaska. Univ. Alaska, Inst. Mar. Sci. Tech. Rept. IMS R82-1. 221 pp. (ADF&G, Habitat Library, #B1973.)

In this study, an inventory of infaunal species was made along with sedimentological and water column measurements at selected stations in the Dutch Harbor area. A number of stations adjacent to the areas where shellfish processing waste was being deposited showed accumulations of plant debris. Because of restricted bottom circulation in the area, waste material was not immediately dispersed and water in the area became anoxic in June (1978). Feder and Burrell concluded that stress on the benthic systems in these areas must be common whenever plant material accumulates on the bottom and that additional input of processing wastes could be expected to further alter the benthic infauna. Measurements taken within Dutch Harbor proper found dissolved oxygen concentrations at the base of the water column to be less than 5 ml/l, which was not conspicuously different from that observed a decade previously when organic loading due to processing wastes was much higher. Apparently anoxic conditions occur naturally in Dutch Harbor; however, additional stress to the system would be expected to increase benthic oxygen demand and result in a further reduction of infauna present. No infaunal organisms were surviving under or very close to waste accumulations; however, the negative effects of these wastes were dissipated within relatively short distances of a few hundred meters. Feder and Burrell recommended disposal of wastes into a higher energy environment where tidal action would increase dispersion of the wastes.

Activity: solid waste disposal.

Impact: addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Feder, H.M., L.M. Cheek, P. Flanagan, S.C. Jewett, M.H. Johnson, A.S. Naidu, S.A. Norrel, A.J. Paul, A. Scarborough, and D. Shaw. 1976. The sediment environment of Port Valdez, Alaska: the effect of oil on this ecosystem. U.S. Environmental Protection Agency Ecological Research Series; EPA-600/3-76-086. 322 pp. (ADF&G, Habitat Library, #B0661.)

This report provides a comprehensive survey of the impacts of oil spills upon benthic invertebrate species in Port Valdez.

Simulated crude oil spills resulted in no changes in the sediment load, nickel, vanadium, and organic carbon content. Only under chronic oil dosages did copper and zinc concentrations increase. The general lack of chemical change in oiled sediments is attributed to (1) the inability of glacial sediments to immobilize crude oil and its degradable products and (2) the swift tidal removal of the oil from tidal flat surfaces.

Monthly meiofaunal counts were made at a mid-tide station on three beaches over a 2-yr period from 1972 through 1974. The meiofauna consisted primarily of nematodes and harpacticoid copepods, with representatives of the Protozoa, Cnidaria, Platyhelminthes, Nemertinea, Annelida, Tardigrada, and Arthropoda. Several small macrofaunal species were also sampled, with representatives of Annelida, Mollusca, and Arthropoda found. Most of the meiofaunal species were restricted to the upper 3 cm of sediment.

The bacterial populations were unaffected by single applications of up to 2,000 ppm of oil or by chronic applications applied for several consecutive days during several low tide series. However, when the sediment was enriched _in situ_ by algal growth and oil seepage and in _in vitro_ model systems, the bacteria responded with an increase in biomass, an increase in respiratory activity, and the formation of a sulfide system in sediment columns. It is concluded that oil and other organic matter are removed by tidal action, leaving an organically poor and relatively biologically inactive ecosystem.

Three species of copepods exposed to various levels of oil (200, 500, 1,000, and 2,000 ppm) in the field significantly increased in density within a variable number of oiled plots. Two of the species also demonstrated an increase in reproductive activity in some of the oiled plots. The statistically significant increase in numbers of individuals in conjunction with the increase in reproductive activity for these species suggests that density increments are primarily a reflection of heightened reproductive activity. The responses of the copepods to oil in Port Valdez are in contrast to observations made in the laboratory elsewhere, in which crude oil fractions were found to be toxic to various species of pelagic copepods.

Under the experimental conditions used, petroleum was no longer detectable 2 mo after a 5 d oiling procedure designed to simulate the stranding of a light oil slick. During the experimental period, a significant increase in mortality of an endemic species of clam exposed to oil was noted, as compared to clams in unoiled control plots. (Author's abstract: modified)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Feller, M.C., and J.P. Kimmins. 1984. Effects of clear-cutting and slash burning on streamwater chemistry and watershed nutrient budgets in southwestern British Columbia. Water Resourc. Res. 20(1): 29-40. (ADF&G, Habitat Library, #R5137.)

Two small forested watersheds near Haney in southwestern British Columbia were partially clear-cut, and the slash on one of them was subsequently burned. Streamwater chemistry was monitored in these treated watersheds and an undisturbed control watershed for 2 yr prior to treatment and up to 9 yr after treatment. The chemical parameters that were studied responded differently to the treatments, but there was a general pattern of increased concentrations and fluxs in streamwater for the first 2 to 3 yr following treatment followed by a decline to, and sometimes below, pretreatment values. The most pronounced increases were observed for K and NO_3. It was not possible to determine the exact causes of these changes in concentrations and fluxes, due to the great variability in the ecosystems present. This variability precluded determination of statistically significant changes in annual terrestrial nutrient fluxes and pools. Stream nutrient exports usually were less than 10 kg/ha/yr for each of N, P, K, and Mg, less than 20 exports in harvested logs and in losses to the atmosphere during the slashburn. Clear-cutting and burning caused greater nutrient losses than clear-cutting alone, particularly in the case of N, where the clear-cutting and clear-cutting and burning treatments resulted in total losses of 245 kg/ha and 1293 kg/ha, respectively, for the first 2yr after treatment. (Authors Abstract)

Activity: burning; clearing and tree harvest.

Impact: change in levels of nutrients.

Finlayson, B.J., and S.A. Ashuckian. 1979. Safe zinc and copper levels from the Spring Creek drainage for steelhead trout in the upper Sacramento River, California. California Fish and Game 65(2):80-99. (ADF&G, Habitat Library, #R3867.)

Newly fertilized steelhead trout (Salmo gairdneri) eggs were exposed to different concentrations of two copper to zinc ratio (1:4 and 1:12) wastes and raised to the swim-up fry stage in waste-free water for use in bioassay testing. This was done to determine if prior exposure of the fry affects their sensitivity to the waste. Long-term (60-d) and short-term (96-h) bioassays were conducted on eggs, alevins, and swim-up fry.

The bioassays indicated that eggs were more resistant than alevins and fry to solutions containing both zinc and copper while solutions containing only zinc affected all stages equally. It is the dissolved fractions of these metals, ions in solution, which produce the toxic reactions in fish. At the lower copper-to-zinc waste ratio of 1:12, copper was present in sufficient quantity to increase to toxicity of the waste. The incipient lethal levels (10% mortality) for the period from egg-to-fry were 0.12 mg/l zinc at the lower waste ratio, and 0.10 mg/l zinc and 0.011 mg/l copper at the higher waste ratio. The incipient lethal level of control fry, those which had not been previously exposed to the waste, was 0.03 mg/l zinc. The presence of aluminum and iron in the waste apparently did not affect the toxicity of either zinc or copper. "Safe" levels of zinc and copper for steelhead trout are below 0.03 mg/l and 0.01 mg/l, respectively.

Activity: processing minerals; solid waste disposal.

Impact: change in levels of heavy metals.

Fisheries Research Institute. 1971. The effects of disposal of salmon cannery waste on the marine environment adjacent to some Kodiak Island canneries. In Univ. Washington, College of Fisheries, Fisheries Research Institute. Salmon Cannery Waste Study. Bristol Bay and Kodiak Island, Alaska, 1970. 44 pp. (ADF&G, Habitat Library, #B6254.)

The effects of the disposal of the waste materials from three salmon canneries located at Port Bailey, Alitak, and Larsen Bay, Kodiak Island, on the receiving marine ecosystem were studied during the 1970 salmon canning season. Sampling of benthic organisms by Ekman dredge at the cannery docks showed considerable within-site variability and some contrasts between sites. No consistent seasonal trends in either abundance or species composition were found, indicating no universal trend of reduction or increase of benthic organisms, during the canning season. A marked influx of pelagic fish (Dolly Varden, herring, and whiting) was noted in the cannery areas. These fish were feeding almost exclusively on salmon tissue during the canning season. Invertebrates organisms, especially jellyfish, were also observed to be feeding on particles of fish tissue. Two conclusions were made on the rate of consumption of waste tissue by benthic animals: 1) large pieces of salmon waste were more rapidly consumed in areas away from the canneries, and 2) larger animals such as fish, crabs, and starfish were primarily responsible for the rapid consumption of soft tissues. Depressed dissolved oxygen values were found in the immediate vicinity of the waste discharge, but the area affected was confined to a thin layer of surface water within 75 yd from the disposal site. Tidal currents and wind were identified as key factors affecting the distribution of surface water with low dissolved oxygen.

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen; artificial attractant to biological organisms.

Fletcher, G.L., J.W. Kiceniuk, and U.P. Williams. 1981. Effects of oiled sediments on mortality, feeding, and growth of winter flounder Pseudophleuronectes americanus. Mar. Ecol. Prog. Ser. 4(1):91-96. (ADF&G, Habitat Library, #R3866.)

Winter flounder were exposed to sediments contaminated with Venezuelan crude oil in three laboratory experiments of 4 to 5 mo duration. Two of the experiments were conducted in summer during the flounder's feeding period and one during winter, when they do not feed. Mortalities were observed in all experimental groups during summer but were considerably greater in flounder exposed to oiled sediments than those in unoiled sediments. Oiled sediments aged for a year remained toxic, although less so than freshly oiled sediments. The aged oiled sediments had little or no effect of feeding rates. A control group of flounder showed greater increases in weight and condition factors than did exposed flounder, and flounder from aged oil showed a greater increase in condition than did those exposed to fresh oil. Because winter flounder are obligatory residents of benthic habitats that could become contaminated with oil, these results suggest that in the event of such an occurrence the winter flounder's ability to grow and store enough energy reserves to survive the winter could be reduced. The oil may act as a nonspecific stressor, which in conjunction with the high summer water temperatures and the effects of captivity resulted in significant mortality.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Floc'h, J.Y., and M. Diouris. 1981. Impact du petrole de l'Amoco Cadiz sur les algues de Portsall: Suivi ecologique dans une anse tres polluee. (Impact of Amoco Cadiz oil on the algae of Portsall: ecological survival in a very polluted bay.) In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France. (ADF&G, Habitat Library, #R4328.)

The effect of the Amoco Cadiz oil on the intertidal algae of the coast near Portsall was gradual and extended for at least 8 months after the oil spill. For most algae the importance of the damage, which was restricted, was a function not of their specific sensitiveness but of the duration of contact with the oil, Pelvetia canaliculata and Fucus spiralis of the sheltered rocks being the most affected. No important fluctuation appeared in the zonation of algae during the first year after the spill, except a noticeable extension of the Fucus vesiculosus belt down to its lower limit. (Author's abstract, article in French)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Franklin F.L., and R. Lloyd. 1982. The toxicity of twenty-five oils in relation to the MAFF dispersant tests. Fish. Res. Tech. Rept. No. 70. Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research, Lowestoft, England. 13 pp. (ADF&G, Habitat Library, #B6227.)

This report presents the results of a series of investigations carried out in England between February 1979 and May 1981 to assess the relative toxicities of a range of oils, alone and when treated with three representative dispersants. The tests were primarily intended to identify those oils that were likely to cause special environmental problems if spilt at sea and secondarily to indicate whether more than one oil should be used in the standard tests for oil dispersants. Three types of toxicity test were carried out to determine

a) the acute toxicity of each oil to brown shrimps (Crangon crangon L) within a 96-h exposure period in order to obtain comparable toxicity curves and LC_{50} data;

b) the effect of three selected dispersants (a conventional and two concentrates) on the acute toxicity of each oil to brown shrimps under the conditions of the 'sea' test - a dispersant passes this test if the oil dispersion it produces is no more toxic than physically dispersed oil;

c) the relative toxicity of each oil to common limpets (Patella vulgata) under the conditions of the 'beach' test - a dispersant passes this test if it is no more toxic than the reference oil used.

All of the 19 samples of crude oil tested were of broadly similar toxicity, and there appeared to be no difference between fresh imported oils (8 samples) and North Sea crude oils (11 samples). Although the light oils tended to be the most toxic, there did not appear to be a general relationship between toxicity and viscosity. Thus, in broad terms, the toxicity tests did not identify among those commonly carried in the North Sea an individual oil that might cause special concern if spilt.

None of the 'sea' tests using the crude oils with three dispersants gave results which were substantially different to those obtained with fresh Kuwait oil. The use of a single oil as a standard in the MAFF 'sea' test therefore appears to be justified, and the criterion of acceptability would apply to other crude oils even though fresh Kuwait oil was one of the least toxic of those tested. (Author's conclusions: partial)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Fraser, J.A.L., and E.R. Clark. 1984. The effects of a settled industrialized domestic sewage works effluent from percolating filters on the survival and growth of various stages of rainbow trout, Salmo gairdneri. J. Fish. Biology 24:13-27. (ADF&G, Habitat Library, #R4954.)

This paper addresses the influence of settled effluent from percolated filters on different life stages of rainbow trout (Salmo gairdneri). Work described in the paper is derived from a Ph.D. thesis, submitted by Fraser at the University of Aston in Birmingham, England, during 1979.

Comparisons are made of mortality, growth, and condition factors over a 50-d period for eleutheroembryos, alevins, 2-mo fry, 4-mo fry, and 1+ rainbow trout under three separate water quality conditions, i.e., tap water, 50% effluent, and 100% effluent from percolating filters. Toxic components of the effluent included a mixture of filterable copper, zinc, lead, nickel, chronium, and cadmium.

There was no significant mortality among life stages in control tap-water, but the LT50 values of life stages in both 50% effluent and 100% effluent revealed significant differences. Intertreatment comparisons showed similar mortalities of eleutheroembryos, of 2-mo fry, and of 1- fish in the three treatments, but LT50 values of 4-mo fry showed significant differences. Growth rates of 2-mo and 4-mo fry were suppressed in both effluents after 7 d, and there was a significant deterioration in the K factor of these life stages after 14 d. Predicted toxicities (the sum of the proportions of the 48-h LC50 of the individual poisons to rainbow trout) were compared with the observed toxicity in 50 and 100% effluent. The relevance of in vivo testing in comparison to predictive techniques is compared.

General observations were as follows: control fish appeared to remain active and swim against the stream current while fish subject to effluent conditions tended to swim with the current to the end of the retaining cage; mortality was greater for 100% effluent than for 50% effluent tests; ascending order of tolerance for both effluents was 2-mo fry, eleutheroembryos-alevins, 4-mo fry, and 1+ fish; and starvation (inhibition of feeding response) probably is an important consequence of continuous exposure of early life staged rainbow trout to effluents from percolating filters.

The authors state that the results of their study are in agreement with those of other workers who have conducted both acute and chronic tests with a variety of added poisons in clean water.

Activity: sewage disposal.

Impact: change in levels of heavy metals.

Fredriksen, R.L. 1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. USDA: Forest Service Res. Pap. PNW-10. 19 pp. (ADF&G, Habitat Library, #B6257.)

Although this report is limited to one set of three watersheds and a relatively short period of time, it clearly provides an estimate of sedimentation that can and does occur in the western Cascades. Where topography in this province is steep (valley sideslopes and drainage headwalls greater than 60%) and where soils are unstable, landslides are the major source of stream sedimentation. Their occurrence is more frequent where logging roads intersect stream channels. Slide-producing storms occur in this province at 3-to-4-yr intervals and must be considered in harvesting plans.

This study suggests that a minimal deterioration in water quality arises from sedimentation where disturbance from road construction is minimized by reduction of mid-slope road mileage through the use of specially designed yarding systems. Where mid-slope roads must be constructed across steep sideslope or headwall areas, care should be taken to stabilize roads. In the logging operation, every effort should be made to minimze disturbance to the streambed by keeping slash and debris out of the streams. (Author's conclusions: modified)

Activity: grading/plowing.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Fredriksen, R.L., D.G. Moore, and L.A. Norris. 1975. The impact of timber harvest, fertilization, and herbicide treatment on streamwater quality in western Oregon and Washington. Pages 283-313 in B. Bernier and C.H. Winget, eds. Forest soils and forest land management. Proceedings, Fourth North American Forest Soils Conference, Laval Univ., Quebec, August 1973. (ADF&G, Habitat Library, #R1780.)

This paper describes the impacts of forest management practices on streamwater quality in the Douglas-fir region. The authors present a) a conceptual base for understanding the precesses of soil erosion and stream sedimentation and the outflow of native nutrients, fertilizers, and herbicides in streams and b) recent research findings from Cascade and Coast Range watersheds that illustrate these concepts. The authors' conclusions are as follows:

1) Sedimentation of forest streams after timber harvest increases exponentially with increasing angle of slope in three experimental watersheds in western Oregon. Forest roads that crossed steeply inclined stream channels caused much greater levels of sedimentation than roads on ridge tops, and more time was required for soils to stabilize from clear-cutting and forest roads in the steeper country. Although there may be moderate increases in sedimentation on stable slopes of intermediate steepness following logging, rates may return to normal within 4 to 5 yr when revegetation is rapid. In very steep topography, where soil strength is nearly in balance with the potential for downsliding, the largest sedimentation increases are expected as a result of frequent mass erosion events. These levels persisted for more than 11 yr after harvest at one site.

2) Nutrients are lost following clear-cutting, but the loss decreases rapidly with revegetation. Maximum NO_3-N concentration increases in streams have remained well below toxic levels. Nutrient losses by soil erosion are of greater importance on steeper slopes.

3) Forest fertilization-water quality studies indicate that N concentration in streams does not increase to levels exceeding published standards. Total loss of applied nutrient is small and should not have any measurable impact on eutrophication in downstream impoundments. Long-term consequences of repeated forest fertilization on water quality is still undetermined.

4) Herbicides enter streams primarily by drift or direct application to surface waters. Overland flow and leaching of herbicides are relatively unimportant factors in forest stream pollution. (Authors conclusions: modified)

Activity: chemical application; clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; change in levels of nutrients.

Friocourt, M.P., Y. Gourmelun, F. Berthou, R. Cosson, and M. Marchand. 1981. Effets de la pollution de l'Amoco Cadiz sur l'ostreiculture en Bretagne nord: Suivi chimique de la pollution, de l'epuration et de l'adaptation. (Effects of Amoco Cadiz pollution on oyster culture in north Britany: Chemical studies of pollution, depuration, and adaptation). In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, internatioal symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4327.)

Oyster areas were heavily polluted by the Amoco Cadiz oil spill. Levels of hydrocarbons in oysters collected from Aber Benoit and Aber Wrac'h estuaries were measured by two analytical methods: spectrofluorometry and gas chromatography on the glass capillary column.

Three experiments were simultaneously conducted:

1) Keeping oysters in initially polluted areas. Within 16 mo, spontaneous depuration of heavily polluted oysters was incomplete. Residual levels of polyaromatic hydrocarbons (PAH) were left abnormally high. The concentration and distribution of the hydrocarbons in oysters were noticeably modified during this time. Aliphatic hydrocarbons were rapidly encountered at normal concentrations and distributions, whereas PAH were preferentially accumulated. PAH fraction occured at the extent of about 75% of total hydrocarbons. Aromatic fraction accumulated by oyster tissues consisted of sulfer PAH as dibenzothiophene and its alkyl-substituted analogs. The data can be interpreted as indicating that modifications in the composition of hydrocarbons retained by oysters occured externally to oysters themselves.

2) Transferring polluted oysters to uncontaminated areas. Accumulated hydrocarbons were rapidly, although incompletely, discharged when polluted oysters were returned to oil-free sea water. Within 8 mo, residual hydrocarbons were encountered at significant levels, especially for PAH. Aromatic hydrocarbons were retained longer than the n-alkanes. It is shown that discharge of petroleum hydrocarbons by oysters under field conditions depended on the exposure time to pollution. The oysters exhibited definite signs of physiological stress due to prolonged exposure to oil.

3) Exposing nonpolluted oysters to oil-contaminated areas. When exposed to oil-polluted seawater and sediments, oysters rapidly accumulated a wide variety of petroleum hydrocarbons. Levels and distribution of hyrocarbons occured at the same extent as in the first experiment. It is concluded that oysters could be used as a test organism for monitoring long-term hydrocarbon pollution.

The implications of the results for the oyster industry are discussed. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Fritz, E.S. 1980. Cooling water intake screening devices used to reduce entrainment and impingement. USDI:USFWS - Office of Biological Services, Washington, DC. Publ. No. FWS/OBS-76 20.9 21 pp. (ADF&G, Habitat Library, #B2426.)

Cooling-water intake devices are identified and described. The information presented can be used in assessing any type of water-intake system, including those used in irrigation, industrial, and municipal withdrawals.

Most screening devices or systems presently available can be included in several general categories. These are modified vertical-traveling screens, single-entrance double-exit screens, horizontal-traveling screens, passiveintake screens, radial wells, artificial filter beds, and porous dikes. For each device the location, limitations or restrictions, evidence for reducing entrainment and impingement, and major unresolved problems are also discussed.

Section 316(b) of the Clean Water Act requires that " . . . the location, design, construction, and capacity of cooling-water intake structures reflect the best available technology available for minimizing adverse environmental impact." The best available technology, exclusive of cost, is most often represented by closed-cycle cooling systems (e.g., cooling towers, ponds, canals) that reduce the volume of water that must be withdrawn from the source of the cooling water. The reduction in the volume of water results in a subsequent decline in the number of organisms drawn toward or into the cooling system, or both. Due to the expense of some closed-cycle cooling systems and their potential environmental impacts (e.g., salt drift, icing, unproductive land use), substantial effort has been expended to identify or develop alternative intake systems and devices.

Closed-cycle cooling systems reduce the volume of cooling water withdrawn from a water body by at least 90% of that required for once-through cooling systems. In estimating the effectiveness of closed-cycle cooling with one-through cooling systems fitted with a vertical traveling screen (VTS), the author concluded that closed-cycle cooling minimizes the biological impact by at least 90%. To be considered an alternative to closed-cycle cooling, a once-through cooling system with its screening device must be shown to reduce impingement and entrainment mortality by 90% of that expected of a once-through system fitted with a VTS.

The intake technologies described in this topical brief show some promise for reducing the impacts of entrainment and impingement. However, evidence is insufficient to demonstrate that any of these intake systems along, or in combination, can afford the protection that is presently attainable by closed-cycle cooling. The most effective systems, the radial well and artificial filter bed, can only provide enough water for make-up water in closed-cycle systems. The screening devices, both active and passive, do not yet have a sufficient database to demonstrate effectiveness or reliability. More experience is needed operating and maintaining these devices before they can be considered as alternatives to closed-cycle cooling or minimizing the adverse impact of cooling-water intakes.

Another subject that must be considered when assessing screening devices that require the impingement of an organism is the fish bypass or return system. The success of the screening system is greatly dependent on returning or bypassing fish, eggs, and larvae to the source water with a high probability for their survival. Any system that minimizes damage to organisms during their capture but damages or overly stresses them when released cannot be considered the best technology available. Fish-return systems differ greatly at different power plants. These differences have inhibited the evaluation of the return portions of water-intake systems.

Activity: water regulation/withdrawal/irrigation.

Impact: impingement or entrainment or entanglement.

Froehlich, H.A. 1979. Soil compaction from logging equipment: effects on growth of young ponderosa pine. J. Water Soil Conserv. 34(6):276-278. (ADF&G, Habitat Library, #R3850.)

Compacted soils in tractor skid trails produced by harvesting ponderosa pine proved to be long-lasting. Soil densities in skid trails at 7.6- and 15.9-cm depths and 22.9-and 30.5-cm depths were 18 and 9% greater, respectively, than those of adjacent, undisturbed soils 16 yr after logging. Growth of residual young pine trees related negatively to the area and intensity of soil compaction in the root zone. Moderately impacted trees showed a 6% reduction in growth rate, and heavily impacted trees showed a 12% reduction over a 16-yr period. Although this paper does not pertain directly to effects on aquatic biota, the information on soil compaction relateS to general hydrology of the watershed and is therefore included. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: physical disturbance of substrate materials.

Gammon, J.R. 1970. The effect of inorganic sediment on stream biota. Water Pollution Control Research Series 18050 DWC 12/70. 141 pp. (ADF&G, Habitat Library, #B3484.)

Fish adopted to moderately unpolluted water (bass) and fish adaptable to more severe pollution (suckers) were all found to fluctuate over a 4-yr period in response to varying quantities of sediment produced by a crushed limestone quarry that discharged effluent into an Indiana creek. Macroinvertebrate (various taxa) population abundance fluctuated similarly to fish species. Light inputs of sediments that increased the suspended solid load less than 40 mg/l resulted in a 25% reduction in macroinvertebrate density below the quarry. Heavy inputs caused increases of more than 120 mg/l, including some deposition of sediment, and resulted in a 60% reduction in population density of macroinvertebrates. Population diversity indices were unaffected by changes in density because most taxa responded to the same degree. Experimental introductions of sediment caused immediate increases in the rate of invertebrate drift proportional to the concentration of additional suspended solids.

The standing crop of fish decreased drastically when heavy sediment input occurred in the spring, but fish remained in pools during the summer when the input was very heavy and vacated the pools only after deposits of sediment accumulated.

After winter floods removed sediment deposits, fish returned to the pools during spring months and achieved levels of 50% normal standing crop by early June. Slight additional gains were noted during the summer even with light sediment input. One species of bass was resistant to sediment, but its growth rate was lower below the quarry than above. Most fish were much reduced in standing crop below the quarry.

Fish populations did not recover within 2 yr following the noted decline, during conditions of relatively light sediment input by the quarry. The author concludes that recovery to abundance levels measured prior to quarry sediment input would probably never be achieved. (Authors abstract: modified)

Activity: processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

Geen, G.H., and F.J. Andrew. 1961. Limnological changes in Seton Lake resulting from hydroelectric diversions. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 8. New Westminster, B.C., Canada. 76 pp. (ADF&G, Habitat Library, #B6181.)

Limnological changes occurring in Seton Lake and Seton Creek as a result of hydroelectric diversions from Bridge River and Cayoosh Creek into Seton Lake were investigated to provide information that would be of value in assessing effects of other proposed diversions in the Fraser River system. The changes included reduced temperatures and dissolved mineral content and increased turbidity and flushing rate. Plankton production appeared to be greatly reduced, primarily because of a pronounced increase in turbidity. (Author's abstract)

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in turbidity or suspended sediments; change in levels of pH, alkalinity, or hardness.

Gehrs, C.W. and G.R. Southworth. 1975. Investigating the effects of chlorinated organics. Pages 329-342 in R.L. Jolley, ed. Water chlorination, environmental impact and health effects. Vol. 1. Proceedings of the conference on the environmental impact of water chlorination, Oak Ridge, TN, Oct. 22-24, 1975. Ann Arbor, Michigan, Ann Arbor Science Publications. (ADF&G, Habitat Library, #R3973.)

The recent identification of stable chlorine-containing organics arising from the chlorination of natural waters has revealed a group of reaction products whose toxicities to aquatic organisms are unknown. In this paper we present information on the toxicity of two chlorinated compounds (5-chlorouracil and 4-chlororesorcinol) and a mixture of identified chlorinated organics to zooplankton and fish. We compare data emphasizing differences in relative toxicity depending on the response parameter used. Problems associated with studying individual compounds and complex mixtures are discussed, and a systematic approach for overcoming the identified shortcomings is presented. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Gent, Jr., J.A., R. Ballard, A.E. Hassan, and D.K. Cassel. 1984. Impact of harvesting and site preparation on physical properties of piedmont forest soils. Soil Sci. Soc. Am. J. 48:173-177. (ADF&G, Habitat Library, #R3826.)

The impact of intensive forest management practices on soil bulk density, aeration porosity, and saturated hydraulic conductivity was examined to a depth of 0.3 m before harvest, after harvest, and after site preparation. Harvesting caused significant changes in soil physical properties to an average depth of 0.17 m in whole tree harvest plots and 0.22 m in skid trail plots. Disking was effective in restoring soil physical properties to preharvest levels in the upper 0.07 to 0.12 m of soil. Soil compaction in chop/burn plots may result in reduced root growth because of mechanical impedance, reduced aeration, or both. Based on these data the authors conclude that harvesting operations should be planned carefully to minimize the total area in primary skid trails. All areas should be disked to ameliorate some of the damage to soil physical properties incurred during the harvesting operation. However, research is needed to determine if the amelioration of compacted soils by disking adequately conpensates for the displacement of organic matter and topsoil normally associated with the piling operation and soil erosion subsequent to disking. If not, chopping may be the preferred method of site preparation. (Author's conclusion: partial)

Activity: clearing and tree harvest.

Impact: physical disturbance of substrate materials.

Gerber, R.P., E.S. Gilfillan, B.T. Page, D.S. Page, and J.B. Hotham. 1980. Short and long-term effects of used drilling fluids on marine organisms. Pages 882-911 in Research on environmental fate and effects of drilling fluids and cuttings. Vol. 2: Symposium proceedings. 1980. January 21-24. Lake Buena Vista, Florida. 1,122 pp. (ADF&G, Habitat Library, #R5034.)

In this study, 96-h static bioassays were used to determine the relative toxicity of five drilling fluids collected from offshore drilling rigs and various components of these fluids to cold-water marine animals, including blue mussels, ocean scallops, northern shrimp larvae, green crabs, and killifish. With few exceptions, the adult animals exposed for 96 h to the various fractions of the drilling fluids, showed little mortality. Most organisms had cellular enzyme activities different from the controls, and differences in enzyme activity rates were apparent for the different drilling fluids or components. The authors concluded that drilling muds are most toxic to larval marine organisms and, though much less toxic to adults, sublethal stress was evident. Long-term effects were demonstrated by reduced growth rates in mussels.

Activity: drilling.

Impact: change in levels of heavy metals; change in levels of hydrocarbons.

Gerke, R.J., and V.W. Kaczynski. 1972. Food of juvenile pink and chum salmon in Puget Sound, Washington. Washington Department of Fisheries. Tech. Rept. No. 10. 27 pp. (ADF&G, Habitat Library, #B3608.)

Pink and chum salmon fry frequently reside in shallow shoreline areas after migrating to salt water. Pink and chum salmon fry were collected from three areas of Puget Sound, Washington, from April through June, 1970. The results of this field study indicated that epibenthic organisms and not zooplankton are the most important food types. These small marine crustaceans inhabit a water layer near the bottom in the littoral to sublittoral zone. The authors state that the ecological zone that the epibenthic organisms inhabit is of primary concern when considering alterations of shoreline areas and beaches. Piers, jetties, landfills, marinas, and bulkheads not only remove living area for fish, but they eliminate habitat that supports the prey of some fish species.

Activity: filling (aquatic and wetland habitats).

Impact: addition of physical barriers - partial obstructions.

Gibbons, D.R., and E.O. Salo. 1973. An annotated bibliography of the effects of logging on fish of the western United States and Canada. USDA/FS - Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Gen. Tech. Rept. PNW-10. 145 pp. (ADF&G, Habitat Library, #B0007.)

This bibliography is an annotation of the scientific and nonscientific literature published on the effects of logging on fish and aquatic habitat of the western United States and Canada. It includes 278 annotations and 317 total references. Subject areas include erosion and sedimentation, water quality, related influences upon salmonids, multiple logging effects, alteration of streamflow, stream protection, multiple-use management, streamside vegetation, stream improvement, and descriptions of studies on effects of logging. The authors identify the major impacts to the environment as follows:

1. Introduction of sediments
    a. Bedload sediments:
        1) Reduced dissolved oxygen caused by reduced inter- and intragravel waterflow
        2) Physical barrier to the emergence of alevins
        3) Lowered production of aquatic plants and invertebrates
        4) Damage to eggs by adhesion to the chorion
        5) Reduced catchability of sport fish
    b. Suspended sediments:
        1) Erosion of gill membranes
        2) Degradation of rearing habitat
        3) Lowered production of aquatic plants and invertebrates

2. Altered streamflow regimes

3. Introduction of logging debris:
    a. Barriers to movement by juveniles and spawning adults
    b. Reduced dissolved oxygen as a result of high biological oxygen demand

4. Degradation of rearing habitat through streambank erosion

5. Altered temperature regimes:
    a. Increased summer temperatures
    b. Decreased winter temperatures

6. Alterations in stream energy resources

7. Indiscriminate use of pesticides and herbicides

8. Altered chemical water quality regimes by the exposure of mineral soils and indiscriminate use of fertilizers.

Activity: burning; chemical application; clearing and tree harvest; grading/plowing; stream crossing - structures.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen; change in levels of biocides; change in levels of nutrients.

Goertner, J.F. 1981. Fish-kill ranges for oil well severance explosions. Naval Surface Weapons Center, White Oak, Maryland. NSWC TR 81-149. 30 pp. (ADF&G, Habitat Library, #R0459.)

Abandoned wellheads are usually severed 15 to 20 ft below the ocean bottom by an explosive change inside the wellhead casing. Goertner computed the extreme values of compression and extension of the fishes' swim bladder to estimate lethal ranges from wellhead severance explosions.

The results of Goertner's model show that significant fish kills (for fish with swim bladders) can occur near the surface to a range of 900 ft for 1 oz fish for explosions at a depth of 200 ft. Larger fish near the surface are less vulnerable to injury from explosion. One pound fish near the surface can be killed to a range of 300 ft. Near the bottom, significant kills of all sizes of fish are limited to a range of 70 ft.

In a water depth of 500 ft, the hazard to all fish is considerably reduced and is probably significant only for small fish. One-ounce fish near the surface can be killed to a range of 700 ft. The only other fish that can be injured are those near the bottom within 30 to 40 ft from the charge. For severance explosions in water of 1,000 ft depth, no significant kills of swim bladder fish occur.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Golden, M.F. and Twilley. 1976. Fisheries investigation of a channelized stream, Big Muddy Creek Watershed, Kentucky. Trans. Kentucky Acad. Sci., 37:85-90. (ADF&G, Habitat Library, #R5100.)

This preliminary survey was undertaken to broaden the database on the fishes of the Big Muddy Creek watershed, Butler and Logan counties, Kentucky. Fish collections and water quality characteristics are reported for four stations in the watershed for August 1974. Thirty-one species of fishes were collected during the survey, bringing the total kinds of fishes known from the Big Muddy Creek drainage to 40. Biomass and number of species were reduced significantly in channelized areas as compared to unchannelized areas. This indicates full recovery has still not occurred after 33 yr, since the last channel maintenance was completed in 1941. Water quality was generally within acceptable limits established by the State of Kentucky for all sampling stations. Therefore, habitat alteration is the likely cause for the reductions in fish diversity and biomass. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; introduction or removal of species.

Goldman, J.C., and H.L. Quinby. 1979. Phytoplankton recovery after power plant entrainment. J. W. P. C. F. 51(7): 1816-1823. (ADF&G, Habitat Library, #R3645.)

This report assesses the impact of water chlorination by power-generating plants. The results of this study support the notion that not all phytoplankton cells are killed during short-term chlorination in entrainments and that those surviving cells can grow and multiply at unrestricted rates. Not only did recovery of the entrained phytoplankton occur, but there were no prolonged or permanent effects on the growth rates of the natural populations. The authors conclude that cells surviving chlorination are capable ofquickly reestablishing prechlorination growth rates. However, the authors discuss the impact of entrainment on larval instars of species that spawn intermittently.

Activity: water regulation/withdrawal/irrigation.

Impact: impingement or entrainment or entanglement; change in levels of chlorinated compounds.

Gordon, R.W., and J.A. Servizi. 1974. Acute toxicity and detoxification of kraft pulp mill effluent. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 31. New Westminister, B.C. Canada. 26 pp. (ADF&G, Habitat Library, #B6178.)

Substandard detoxification by a biobasin with 24 treatment times and acute toxicity of effluent bypassing treatment prompted this 10-mo study. The mill employed an effluent diversion system whereby contaminated effluents could be diverted to a spill lagoon for transfer to the biobasin. Records indicated that diversions ranging from minutes to hours occurred virtually each day and the spill lagonn functioned as a surge basin. Conclusions from the study were as follows:

1) Combined effluent was generally acutely toxic to fingerling sockeye salmon and failed to meet provincial and federal government objectives and regulations.

2) Resin acids were implicated as primary factors contributing to highly toxic combined effluents, but neutral compounds apparently contributed to toxicity as well.

3) Combined effluent was consistently detoxified by an estimated mean of 99 h of biological treatment. Addition to the present treatment system of an aerated lagoon capable of approximately 4.5 d treatment time, is recommended in order to meet governmental objectives and regulations for this mill. Addition of primary sedimentation to protect the aerated lagoon from accumulating solids originating in the combined effluent is recommended.

4) In-plant facilites are required to lessen the occurrence of spills or other upsets. However, a spill lagoon should be retained to absorb the shock of spills and upsets that escape in-plant control. (Author's conclusions)

Activity: processing lumber/kraft/pulp; sewage disposal.

Impact: change in levels of other toxic compounds - other.

Gore, J.A., and L.S. Johnson. 1980. Establishment of biotic and hydrologic stability in a reclaimed coal strip mined river channel. Institute of Energy and Environment, Univ. Wyoming, Laramie. 115 pp. (ADF&G, Habitat Library, #B4033.)

Analysis of the changes in benthic invertebrates, fish, suspended sediment load, and hydraulic profile of a coal strip-mined reclaimed channel of the Tongue River in Wyoming was conducted for a period of 1 yr. The authors present various recommendations on the effectiveness of the reclamation project.

The substrate of medium cobble appeared to be the best choice for benthos colonization. Benthic colonization has been shown to be a function of distance from upstream source areas, since arrival of benthos to new areas is primarily by passive drift. Passive drift also contributes to habitat complexity. Thus a potentially reclaimable stripped section can be no longer than 3 m (4.8 km). These predictions are based on models derived from colonization data.

Snags were the most frequently used areas by fish. Because of slight local changes in sinuosity of the river, the cover provided by two snags was altered. The authors recommend the addition of snags during initial construction to compensate for changes in sinuosity. If fish with a small home range (such as sculpin) are good indicators of a stable fish community.

The substrate had become cemented following mining, due in part to normally high suspended loads in the stream during late summer months. Large boulders placed in the thalweg (the line of deepest channelization) of the channel provided good pooling habitat when boulders freeze-fractured in the winter months. If this did not occur, some gravel bars were formed providing potential spawning sites. Inundation of lower end riprap provided good rock bass and smallmouth bass habitat. The authors recommend the placement of large boulders in shallows of pool areas to duplicate this habitat. Maturation of embankment vegetation was expected to lower suspended sediment concentrations. (Author's abstract: modified)

Activity: dredging; filling (aquatic and wetland habitats); processing minerals.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials; change in levels of other toxic compounds - other.

Gradall, K.S., and W.A. Swenson. 1982. Responses of brook trout and creek chubs to turbidity. Trans. Am. Fish. Soc. 111:392-395. (ADF&G, Habitat Library, #R2761.)

The influence of red-clay turbidity on behavior and distribution of brook trout and creek chubs was measured in the laboratory. Creek chubs preferred highly turbid water (56.6 FTU) over moderately turbid water (5.8 FTU). Brook trout demonstrated no preference. In moderately turbid water, both species were more active and used overhead cover less than in clear water. The results indicate turbidity may represent an important isolating mechanism that promotes production of creek chubs. (Author's abstract: modified)

Activity: clearing and tree harvest; dredging; grading/plowing.

Impact: change in turbidity or suspended sediments.

Graham, J.L., and F.D. Schaumburg. 1969. Pollutants leached from selected species of wood in log storage waters. Page 99-114 in Proceedings, industrial waste conference, 24th May 6-8, 1969. (ADF&G, Habitat Library, #R3831.)

This study was undertaken to quantitatively evaluate the rate at which selected indicators of pollution leach or diffuse from logs floating in fresh and saline water. The relative contributions from exposed bark, peeled surfaces, and crosscut end sections were determined. Douglas fir and ponderosa pine logs were used in all tests. Major conclusions of this work are as follows:

1) Bark contributes most of the color-producing substances leached from floating logs.

2) Ponderosa pine logs yield significantly greater quantities of organic matter than Douglas fir logs.

3) Intact bark tends to reduce the initial rate of loss of soluble organic matter from logs.

4) Cross-cut ends of log sections tend to expedite the release of color and soluble organics.

5) The concentration of soluble organics in holding water affects leaching rate.

6) The extraction of soluble organics from floating logs occurs at a near constant rate in flowing waters.

Activity: log storage/transport.

Impact: change in levels of other toxic compounds - bark or log leachates.

Graynoth, E. 1979. Effects of logging on stream environments and faunas in Nelson. New Zealand J. Mar. Fresh. Res. 13(1):79-109. (ADF&G, Habitat Library, #R3836.)

The effects of various logging practices on stream environments and faunas were studied at the Golden Downs State Forest in Nelson. Comparisons were made between the features of a control stream with an unmodified forest catchment and three streams whose catchments had been affected by different logging practices. Measurements were made of stream flow, water temperature, stream bed sedimentation, suspended sediment and dissolved solids concentrations, and the abundance of benthic invertebrates and fishes.

Clearcutting to the stream's edge, together with inappropriate roading and bridging techniques, caused great changes in stream environments and faunas. Excessive amounts of waste timber and soil entered streams and stream bed loads, and suspended sediment and dissolved solid concentrations increased. In comparison to the control stream water temperatures increased in summer by up to 6.5°C and decreased in winter by as much as 2.5°C. In one stream the benthic invertebrate fauna was greatly modified; there was a reduction in the abundance of Plecoptera and certain Ephemeroptera nymphs, and an increase in the abundance of oligochaetes, chironomids, and Deleatidium nymphs. Fishes, (no species which exist in Alaska) were also reduced in numbers in this stream.

In January 1971 numerous brown trout (Salmo trutta) and other fishes died in the Motueka River, and there are indications that this was due in part to low dissolved oxygen concentrations following excessive sedimentation of the river bed caused by unsatisfactory logging practices. In general, the physical and chemical changes found in the stream environments were similar to those found overseas, but those noted in the invertebrate and fish fauna were rather different: e.g., logging had different effects on the abundance of Diptera, Ephemeroptera, and Trichoptera and on trout survival and migration.

A protective buffer strip of unlogged vegetation was left alongside one stream, and the remainder of the catchment was clear-cut. In comparison to the other streams, there was relatively little change in the aquatic environment and fauna. Although stream flows and nitrate concentrations were considerably higher than in the control stream, these differences may have been natural and not a consequence of the logging operations. Similar results have been found overseas, and it is concluded that, provided measures are taken to reduce erosion, buffer strips will be effective in reducing the effects of logging operations on stream environments and their faunas in other forests throughout New Zealand. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; change in level of dissolved oxygen, nitrogen.

Greer, G.L. 1976. Avoidance by juvenile coho salmon of effluent contaminated surface waters in the vicinity of a coastal pulp mill in British Columbia. Fish. Mar. Serv. Res. Dev. Tech. Rept. 666. 28 pp. (ADF&G, Habitat Library, #B6262.)

Conventional laboratory methods were used to measure the avoidance response of juvenile coho salmon to effluent contaminated surface waters at a location 0.24 km southeast of a pulp mill outfall in Stuart Channel, British Columbia. Surface water was avoided during ebb tides when tidal currents set onto the study site from the outfall, but the response was insignificant during flood tides. The avoidance results corroborate the oceanographic characteristics of effluent dispersal in the channel. (Author's abstract)

Activity: processing lumber/kraft/pulp.

Impact: change in levels of other toxic compounds - sulfurous compounds; change in levels of other toxic compounds - other.

Greer, G.L., and G.J. Kosakoski. 1978. Avoidance of seawater dilutions of kraft pulp mill effluent by seawater acclimated pink salmon fry. Fish Mar. Serv. Tech. Rept. 831. 11 pp. (ADF&G, Habitat Library, #B1213.)

Seawater-acclimated pink salmon fry (Oncorhynchus gorbuscha), ages 2 to 4 mo, were used to measure avoidance of bleached kraft pulp mill effluent (BKME) diluted in sea water in laboratory experiments in British Columbia. BKME was avoided at concentrations ranging from 0.8 to 15.5% full strength effluent, but the avoidance was largely a response to lower salinity of the test water caused by addition of nonsaline BKME. It remains uncertain whether the salinity-induced avoidance behavior observed in the pink salmon fry also functions in the natural environment to orient them away from the low-salinity surface waters of kraft mill surface outfalls. (Author's abstract: modified)

Activity: processing lumber/kraft/pulp.

Impact: change in level of salinity.

Griffith, J.S, and D.A. Andrews. 1981. Effects of a small suction dredge on fishes and aquatic invertebrates in Idaho streams. N. Am. J. Fish. Manage. 1:21-28. (ADF&G, Habitat Library, #R3581.)

A typical dredge (intake diameter 7.6 cm) was operated on four small Idaho streams during July-September 1980 to evaluate some of the effects on aquatic organisms that may result from the use of small suction gold-dredges. Mortality of eggs, sac fry, and fingerlings of several species of trout were monitored, as was that of benthic invertebrates that were processed (entrained) through the dredge. The ability of invertebrates to recolonize a dredged area was assessed.

Uneyed cutthroat trout (Salmo clarki) eggs experienced 100% mortality within 1 h after entrainment. Of the live stages tested in this study, un-eyed eggs are clearly the most susceptible to damage from suction dredges. Uneyed eggs are extremely sensitive to shock 1-2 d after fertilization until they eye-up. From these results, it is anticipated that total mortality would result for trout eggs of any species if disturbed by suction dredge during that period.

Eyed cutthroat trout eggs showed means of 29 and 35% for 1-h and 36-h mortalities, respectively. The 19% mortality of eyed eggs of hatchery rainbow trout (S. gairdneri) after 10 d was similar to that of the control group.

Hatchery rainbow trout sac fry that were entrained through the dredge experienced 83% mortality after 20 d as compared with 9% for the controls. Yolk sacs were detached from approximately 40% of the fry during entrainment.
Fewer than 1% of the 3,623 invertebrates entrained showed injury or died within 24 h. Most of the dead were Centroptilum mayflies that were undergoing emergence at the time of dredging.

Most of the recolonization of dredged plots by benthic invertebrates was completed after 38 d.

Activity: dredging; processing minerals.

Impact: impingement or entrainment or entanglement.

Griffiths, R.P., B.A. Caldwell, W.A. Broich, and R.Y. Morita. 1982. Long-term effects of crude oil on microbial processes in subarctic marine sediments. Mar. Pollut. Bull. 13: 273-278. (ADF&G, Habitat Library, #R3887.)

Subarctic marine sediments were exposed to fresh Cook Inlet crude oil at a concentration of 50 ppt for 6 to 8 mo. After the sediments were treated they were returned to the approximate location where they were collected and were exposed to natural environmental conditions until they were retrieved for analysis. The results of the study show that the activity of hydrolytic enzymes can be altered in the presence of fresh crude oil at high concentrations in marine sediments and that the effects differ, depending on the organic compounds in the sediments.

This study was designed to maximize the potential effect of crude oil on microbial processes. The measurements of hydrolase activity in studies on the effects of any pollutant aid in understanding the mechanisms involved. Any change in hydrolase activity would imply a change in the normal carbon cycling or marine sediments. Because of the role of bacterial biomass in marine carbon cycling, a reduction in hydrolase activity would further imply a reduction in secondary productivity in the impacted area.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Griswold, C.A., ed. 1981. The barge Ocean 250 gasoline spill. NOAA Tech. Rept. NMFS SSRF-751. (ADF&G, Habitat Library, #R4566.)

On 16 March 1978, the barge Ocean 250 grounded on Watch Hill Reef 1,006 m off Watch Hill, Rhode Island. An estimated 2.6 million liters of gasoline was spilled into Block Sound.

Results of cytogenetic analyses indicated maximum damage occured in fish eggs collected in plankton and neuston samples in the spill area. Membrane or embryo damage occured in up to 100% of the fourbeard rockling, Enchelyopus cimbrius, and the yellowtail flounder, Limanda ferruginea, eggs collected over a 4-day period following the spill. Low levels (12 ppb) of hydrocarbons analyzed in the gasoline range were found in the water column at stations in the spill area 36-40 h after rhe spill first began. Zooplankton samples collected from the same area showed traces of hydrocarbons from the gasoline range as did two species of benthic invertebrates, the sea scallop, Placopecten magellanicus, and the hard shell clam, Mercenaria mercenaria. Twenty-three fish samples representing 10 species were analyzed. Five showed levels twice that of the control sample taken from Fox Island, Narragansett Bay. There was no apparent damage to benthic communities, and analyses of zooplankton communities at the time of the spill and 3 wk later showed normal patterns of species composition and abundance.

With the exception of localized damage to fish eggs, there was no apparent discernable damage to fish or invertebrate populations in the area immediately following the spill, and although there were measurable amounts of gasoline hydrocarbon components in a small number of water, fish, and invertebrate samples, there is no evidence that this would cause long-term damage to the populations. Shore surveys did not indicate damage to intertidal flora along Fishers Island, New York, or along the southern Rhode Island coastline. (Author's abstract).

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Griswold, B.L., C. Edwards, L. Woods, and E. Weber. 1978. Some effects of stream channelization on fish populations, macroinvertebrates, and fishing in Ohio and Indiana. USFWS, FWS/OBS-77/46. 24 pp. (ADF&G, Habitat Library, #B1909.)

The effect of stream channelization on macroinvertebrates and fish was studied in four rivers in Ohio (the Olentangy, Sandusky, Hocking, and Little Auglaize) and Rock Creek in Indiana. Sampling areas were located in natural unchannelized areas and nearby channelized areas in all streams. A channelized area mitigated with artificial riffles and deep pools was also sampled in the Olentangy River.

Macroinvertebrate abundance, diversity, and/or biomass was significantly lower in channelized areas of the Olentangy River, Hocking River, and Rock Creek. Drift rates tended to be highest in unchannelized sections of the study streams. Dominant macroinvertebrates in the unchannelized areas were "riffle species," those that are found on substrate surfaces in areas of moving water, whereas dominant species in the channelized areas were burrowing forms adapted for living in soft substrates in standing water.

Game fishes were more abundant in unchannelized areas, whereas some nongame species acheived extremely high abundance in some channelized areas. Diversity and relative abundance of the total fish community were significantly lower in channelized areas of the Olentangy River, but the fish population in the mitigated area approximated that in the natural area.

Creel censuses were run in the study areas of the Olentangy, Sandusky, and Hocking rivers. Comparative results are confounded by the inaccessibility of the natural area of the Hocking River to fishermen and the extensive spring spawning runs of gamefish into all areas of the Sandusky River. A mid- to late-summer sport fishery in the Sandusky River was limited to the unchannelized area. Fishing activity and catch composition in the Olentangy River reflected the fish population in each area. Activity was highest in the mitigated and natural areas, and game fishes were much more abundant in the catch from these areas. Catch rate for gamefish was highest in the natural area.

Rock Creek was channelized in 1974, the first year of the study. Macroinvertebrate abundance in the channelized area 2 yr after channelization approximated that in the natural area; however, macroinvertebrate biomass and game fishes had not recovered to prechannelization levels as indicated by samples from the unchannelized area.

In 1974, an extremely dry year, the Little Auglaize River was completely dewatered for nearly 2 mo along the entire 35-km channelized section. Scattered pools remained in the unchannelized area, although the biota was also adversely affected there. Repopulation of the channelized area from the

Maumee River below occurred within a year, but complete recovery in the unchannelized area, which was isolated from the Maumee by two low-head dams, did not occur in 1975. Still, the presence of some fishes and macroinvertebrates early in 1975 demonstrates some animals found refuge in the unchannelized area and survived.

Recommendations of the study are 1) to include natural or artificial riffles and deep pools in stream alteration projects to provide substrate and habitat for desirable macroinvertebrates and fishes, 2) to minimize alteration of bottom contours and substrates in stream alteration projects, 3) to furnish public access to mitigated areas so use of the fish resource provided may be optimized, and 4) to provide unaltered areas within sizeable channelization projects to serve as biological refuges during periods of drought. (Executive summary)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Groen, C.L. and J.C. Schmulbach. 1978. The sport fishery of the unchannelized and channelized middle Missouri River. Trans. Am. Fish. Soc. 107(3):412-418. (ADF&G, Habitat Library, #R5101.)

A catch survey of 502 km of the Missouri River was conducted from July 1, 1972 to June 30, 1973. The study area encompassed the Gavins Point Dam tailwaters (6.4 km), 84 km of unchannelized river, and 412 km of channelized river. The fishery supported 412.660 angler hours (98.252 angling days) valued at $720,047. Anglers averaged 0.47 and 0.33 fish/h for annual catch and harvest rates, respectively. Catch rate includes fish not kept.

The greatest angling effort and harvest occurred in the tailwaters, but the unchannelized river supported the highest annual catch and harvest rates, 072 and 0.50 fish/h. The unchannelized river also exceeded the channelized river in angler-hours/km, number of fish caught/km, weight harvested (kg/km), and average size of creeled fish. Sauger, channel catfish, and white bass were the most abundant species creeled in the unchannelized river compared to carp, channel catfish, and freshwater drum in the channelized section. The harvest rates indicated that the standing crop of sport fish was considerably greater in the unchannelized than the channelized river. More backwater aquatic habitat and greater habitat diversity in the unchannelized river probably accounted for population abundance differences.

Activity: channelizing waterways.

Impact: change in depth or velocity of water.

Grose, P.L., and J.S. Mattson, eds. 1977. The Argo Merchant oil spill: a preliminary scientific report. NOAA. (ADF&G, Habitat Library, #B2331.)

The grounding of the Argo Merchant 29 nautical miles southeast of Nantucket Island, Massachusetts, triggered intense scientific activity between Dec. 15, 1976, and Feb. 12, 1977. Preliminary results follow.

There is evidence of oil spill contamination in fish, shellfish, ichthyoplankton, and zooplankton populations in the area of the spill. Mortalities of developing cod and pollock embryos in eggs contaminated with oil were observed. Oil globules were found adhering to the surface menbrane (chorion) of 93% of the pollock eggs. Of these eggs, 98% were dead or moribund, as determined through cytogenetic examination. In contrast, only 64% of the cod eggs showed evidence of oil contamination. Noticeable decreases in the abundance of sand launce larvae, which may have been caused by oil, were observed in the spill zone. Large numbers of zooplankters, which are an important food of larval and adult fish, were contaminated with petroleum hydrocarbons similar to No. 6 fuel oil, indicating impact on an important pathway in the food web of the Nantucket Shoals ecosystem. Oil-like material was found in the stomachs of little skate (Raja erinacea) and the gammarid amphipods Gammarus annulatus and Anonyx sarsi. Much of the oil in the copepods was in the form of fecal pellets. These pellets are excreted into the water column, settle to the bottom, and may be concentrated in such benthic filter-feeders as mussels, scallops, and quahogs. Adverse physiological effects were also observed in reduced respiration of scallops, mussels, and an ionic imbalance of blood serum in blackback and yellowtail flounders. The implications of the above results for long-term effects are unclear.

In seabirds, herring and black-backed gulls were hardest hit by the oil slick. Shortly after oil began to flow from the tanker, birds were seen with small patches on breast and abdomen. Later, birds were found with underparts and heads heavily stained. Late in the patrol, badly oiled gulls, appearing to be weakened, began to land on the Vigilant, some accepting food by hand. Although there was a low density of oiled birds in the immediate vicinity of the grounded tanker, oiled birds (primarily murres) washing ashore indicated that oil was affecting birds away from the initial site of spilling.

Marine mammals did not appear to be affected by the surface oil in the few cases where they were observed in the vicinity of the oil. These findings, however, are based on very limited observations.

In conclusion, the outcome of the Argo Merchant oil spill appears to have been fortunate in several respects: (1) the winds were almost continuously offshore, preventing the oil from coming on the beaches; (2) the density of the oil was low enough so that it did not sink and contaminate the bottom; and (3) the spill occured in the winter, when biological activity, productivity, and fishing activities are relatively low. At another time, the effects of a similar oil spill might have been much more serious.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Gundlach, E.R., P.D. Boehm, M. Marchand, R.M. Atlas, D.M. Ward, and D.A. Wolfe. 1983. The fate of Amoco Cadiz oil. Science 221:122-129. (ADF&G, Habitat Library, #R4340.)

Studies of the Amoco Cadiz oil spill off the coast of France are reviewed. The physical environment of the spill, chemical components of the oil, and weathering processes are described. Studies of oil in the water column and subtidal sediments concluded that persistence of oil in the subtidal sediments was related to the physical energy of the site and the type of sediment. A brief summary of the biological effects follows:

- Mortalities of rocky-bottom-dwelling fin fish species in initial few days after the spill; return to normal population densities by the end of 1978 (less than 1 yr after the spill)

- Absence of young soles in Bay of Lannion in 1979

- Flatfish growth in Aber Benoit and Aber Wrac'h reduced in 1978, coincidentally with increased reproductive pathologies and fin necroses

- Lower-than-expected catch of edible crabs in 1978

- Low percentage of egg-carrying female lobsters in 1978-79, could lead to reduced recrutiment in 1982-84

- Initial mortalities of 20-50% in oyster mariculture industry; contamination of surviving oysters prevented marketing; restocking and depuration allowed marketing by spring of 1979 (1 yr after the spill)

- Kelp and algae damaged during cleanup, but communities reestablished by 1980; community structure of algae changed

- Recovery of intertidal marsh areas depended on how heavily they were damaged by oil and cleanup activities

- Heavy initial mortalities of intertidal and nearshore subtidal invertebrate communities in 1978; opportunistic species invaded, with subsequent slow increases in species richness; by 1980 or 1981, most species had reappeared and were undergoing typical seasonal fluctuations

Petroleum residues and the remnants of certain ecological changes at the Amoco Cadiz site are expected to persist for over a decade, particularly where oil is buried in anaerobic zones below the surface.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Hales, L.Z. 1981. Floating breakwaters: state-of-the-art literature review. Dept. of the Army, Coast. Eng. Res. Center, Ft. Belvoir, VA. 280 pp. (ADF&G, Habitat Library, #B4750.)

A multitude of conceptual models of floating breakwaters have been proposed without extensive or complete evaluation of most of these concepts. The technical literature regarding floating breakwater applicability and design procedures is fragmentary and sometimes confusing. Clear, concise guidance does not always exist for those responsible for planning and developing wave protection measures which utilize floating breakwaters. This study reviewed and evaluated the existing technical literature (theoretical, field, and laboratory) on floating breakwater concepts.

While floating breakwaters provide a lesser assurable degree of protection than a permanently fixed breakwater, they are in general less expensive and can be moved from one location to another. The cost of a floating system is only slightly dependent on water depth and foundation conditions. Adequate wave reduction or energy attenuation can be attained by a floating breakwater only if the incident wave is of a relatively low height. A reasonable magnitude appears to be an incident wave height not exceeding 4 ft, with a corresponding wave period not exceeding 4 s. Floating breakwaters can attenuate waves with these incident characteristics to a magnitude tolerable in a small-craft mooring area (wave heights up to 1.5 ft). Open-ocean applications of a distinctly different concept can be formulated to withstand substantial increases in the incident wave characteristics.

A group of prismatic structures contains the simplest forms of floating breakwaters. This group offers the best possibilities for multiple use as walkways, storage, boat moorings, and fishing piers. In addition to mass, the radius of gyration and the depth of submergence appear to significantly influence the attenuation characteristics. As the ratio of breakwater width-to-wavelength increases to values greater than 0.5, the wave attenuatioin features on the mooring and anchoring system becomes substantially less. This occurs because the wave dynamics are exerting forces on a part of the structure in a directioin opposite to those forces on other parts of the breakwater. (Author's Abstract)

Activity: filling (aquatic and wetland habitats).

Impact: addition of physical barriers - partial obstructions; change in level of salinity.

Hall, J.A. 1969. The pulp and paper industry and the northwest. USDA: Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 61 pp. (ADF&G, Habitat Library, #B2533.)

This publication provides a brief history of the pulp and paper industry and gives a general description of the potential effects that various pulping processes have on the environment. Of the three pulping methods reviewed (mechanical, semichemical, and chemical), chemical methods are the most recently developed. Although there are many variations in chemical methods, two primary methods are distinguishable. The sulfite process employs an acid as a primary conditioning agent, whereas the sulfate or kraft process utilizes a strong base. Primary sources of water pollution resulting from these processing methods were identified as follows:

1. Fiber, plus additives and spills from paper-making (barkers, chippers, and log storage) will also contribute.

2. Carbohydrate materials (usually sugars or sugar derivatives) produced in the pulping and bleaching processes; along with these are other chemical substances that also contribute to use of dissolved oxygen from the receiving waters.

3. Lignin and derivatives, plus tanning and other extractives (especially important in calcium-based sulfite mills) may also be of importance in effluent from the pulp of bleached kraft, sulfite, or groundwood mills.

Primary problems associated with pollutant sources were generalized as follows:

1. Various forms of water pollution are the primary problem resulting from pulp and papermill operations because large volumes of water are required as an integral part of the processing procedures.

2. Fiber tends to settle out of the effluent strams near mills and create beds of sludge, which in turn "blanket" the substrate surface. These sludge beds also undergo anaerobic fermentation, which results in the production of water soluble toxins, such as hydrogen sulfide (which is highly toxic to aquatic organisms in relatively low concentrations).

3. Increased biological oxygen demand (BOD) results primarily from the increased concentrations of sugars (although fiber and lignin degradation also contribute).

Activity: processing lumber/kraft/pulp.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in levels of pH, alkalinity, or hardness; change in levels of chlorinated compounds; change in levels of other toxic compounds - bark or log leachates; change in levels of other toxic compounds - sulfurous compounds; change in levels of other toxic compounds - other.

Hall, F.A., Jr. 1979. An evaluation of downstream migrant chinook salmon (Oncorhynchus tshawytscha) losses at Hallwood-Cordua Fish screen. Calif. Dept. Fish and Game, Anadromous Fisheries Branch, Admin. Rept. No. 79-5. 19 pp. (ADF&G, Habitat Library, #R4352.)

This report describes tests performed with downstream migrant chinook salmon (Onchorhynchus tshawytscha) during May and June of 1977 and 1978 at the Hallwood-Cordua fish screen near Marysville, California. The first year's tests were undertaken to determine whether a relationship exists between schooling behavior and predation losses. The second year's tests were performed to identify the specific location of losses at the fish screen. Losses were significantly greater when fingerlings were "dribble" released, rather than released in "mass" groups. Predation losses were significantly greater at the screen face than in the diversion channel upstream from the screen. Sacramento squawfish (Ptychocheilus grandis) were the most important predators observed.

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; addition of physical barriers - impoundments; impingement or entrainment or entanglement; artificial attractant to biological organisms.

Hall, J.D., and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 344-375 in T.G. Northcote, ed. Symposium on salmon and trout in streams. Univ. British Columbia. (ADF&G, Habitat Library, #R2884.)

The effects of two patterns of logging on water quality and fish populations have been studied in three coastal headwater streams. Clear-cut logging of an entire watershed of 71 hectares (175 acres), where about 30% of the area has been harvested and a strip of timber left along the stream. The third watershed of 203 hectares (500 acres) remained unlogged as a control. Prelogging studies began in 1958; access roads were constructed in 1965; and logging took place in 1966.

Substantial changes in temperature and dissolved oxygen content of stream water followed logging in the entirely clear-cut watershed. A maximum temperature of 30°C and a maximum diurnal fluctuation of 16°C were recorded. Comparable prelogging maximums were 16 and 1.5°C, respectively. Dissolved oxygen levels of surface and intragravel water dropped below 2 mg/l during logging operations. Survival of coho salmon and cutthroat trout in the clear-cut watershed were affected by logging, but the significance of the effect could not be fully evaluated. No significant changes in the fish population or its habitat was noted in the patch-cut watershed. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Hall, J.E., and D.O. McKay. 1983. The effects of sedimentation on salmonids and macroinvertebrates - a literature review. ADF&G, Div. Habitat, Anchorage. 31 pp. (ADF&G, Habitat Library, #R2911.)

This report is a summary of the literature regarding the effects of sedimentation on salmonid fishes. The report is designed to consolidate the documented effects of sedimentation on fishes and to provide a working reference for the general public, industry, and resource agency use. Hall and McKay found that sediment deposited in streambed gravels may be detrimental to the survival of eggs, alevin, and fry; sediments deposited on the streambed may decrease the permeability to gravel substrates used for spawning; egg, embryo, and fry survival may decrease because of oxygen depletion, fungal infection, and delayed and impaired emergence; sedimentation may inhibit production of aquatic plants and invertebrate fauna, thus reducing the food available to rearing and resident fish; and streams subjected to heavy unnatural silt loads may require 5 to 20 yr or more to recover, once the source of the sediment has abated.

Activity: channelizing waterways; clearing and tree harvest; dredging; filling and pile-supported structures (aquatic and wetland habitats); grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Hansen, D.R. 1971. Stream channelization effects on fishes and bottom fauna in the Little Sioux River, Iowa. Pages 29-51 in E. Schneberger and J.L. Junk, eds. Stream channelization: a symposium. Special Publ. No. 2. North Central Division, Am. Fish. Soc., Omaha, Nebraska. (ADF&G, Habitat Library, #R5149.)

Differences in certain physical factors, bottom fauna, and fish populations were evaluated in channelized and unchannelized portions of the Little Sioux River, Iowa, during 1969-1971. The Little Sioux River is a turbid, warm-water river located in western Iowa. Characteristic stream channels are meandering, nonuniform channels with heavy vegetative cover in the unchannelized section and straight channels with relatively uniform depth and no heavy vegetative cover in the channelized section. Early channelization (1905-1920) reduced the lower length of river from 63 to 38.5 mi, and channelization completed in 1962 further reduced the length by 4.5 mi, a total reduction of 54%.

Daily fluctuations of water temperature in July were greater, maximum daily water temperatures averaged 1.3°C higher, and mean daily water temperatures 0.3°C higher, in the channelized section than those in the unchannelized section. Consistently higher turbidities were measured in the channelized section during low runoff, averging 31.2% higher than those measured in the unchannelized section.

Composition of bottom fauna was similar in the two sections. Colonization of macroinvertebrates on artificial substrates suggested a lack of suitable attachment areas in the channelized section, also indicated by higher numbers of drift organisms in the channelized section. Numbers of fish species were greater in the unchannelized section. Major changes in species composition of fishes compared to 1950 studies resulted from a control structure installed in 1963 near the mouth, blocking upstream movement of certain species from the Missouri River. Unbaited hoop nets caught more large channel catfish, the most important game species, in the unchannelized section. Hoop net catches and Primacord explosive samples collected greter numbers of smaller channel catfish (less than 254 mm) in the channelized section during late summer and early fall. Possible downstream movement from the unchannelized section, suggested by movement studies and similar growth rates, prevented drastic differences in standing crops of fish between the two areas.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of physical barriers - partial obstructions; introduction or removal of species.

Hansen, D.R., and R.J. Muncy. 1971. Effects of stream channelization on fishes and bottom fauna in the Little Sioux River, Iowa. Iowa State Water Resources Research Institute, IWSRRI-38. 119 pp. (ADF&G, Habitat Library, #B1840.)

Differences in certain physical factors, bottom fauna, and fish populations were evaluated in channelized and unchannelized portions of the Little Sioux River, Iowa, during 1969-1971. Little Sioux River is a turbid, warmwater river located in western Iowa. Characteristic stream channels were a meandering, nonuniform channel with heavy vegetative cover in the unchannelized seciton and a straight channel with relatively uniform depth and no heavy vegetative cover in the channelized section.

Recorded water temperatures showed greater daily flucutations during summer in the channelized section. Maximum and mean daily water temperatures averaged 0.3 and 1.3°C, greater, respectively, in the channelized section during July. Consistently higher turbidities were measured in the channelized section during a period of low runoff, averaging 31.2% higher than the unchannelized section.

Compostion of bottom fauna was similar in the two sections. Colonization of macroinvertebrates on artificial substrates suggested a lack of suitable attachment areas in the channelized section. Higher numbers of drift organisms in the channelized section were further evidence of this. Numbers of fish species were greater in the unchannelized section. Major changes in composition of fishes reported in 1950 studies resulted from a control structure near the mouth, blocking upstream movement of certain species from the Missouri River. Unbaited hoop-net catches revealed the presence of more large channel catfish, the most important game species, in the unchannelized section. Hoop-net catches and Primacord explosive samples collected greater numbers of smaller channel catfish (less than 254 mm) in the channelized section during late summer and early fall. Because of possible downstream movement from unchannelized section into channelized section, suggested by movement studies and similar growth rates, drastic differences in standing crops of fish were not measurable in comparisons of the two areas.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation.

Hansmann, E.W., and H.K. Phinney. 1973. Effects of logging on periphyton in coastal streams of Oregon. Ecology 54(1): 194-199. (ADF&G, Habitat Library, #R3624.)

Changes in stream algal flora were observed during a multi-disciplinary logging study of small watersheds in Oregon. Clearcut logging was applied to one watershed of 71 ha, while a second watered of 304 ha was patch-cut, leaving a bufferstrip of vegetation along the stream channel. A third watershed of 203 ha was not logged but remained as a control. Prelogging and postlogging oxygen levels, temperature, and sedimentation loads were analyzed. Access roads were built in 1963 and logging completed in 1966.

Analysis of the algal communities of the three watershed streams prior to the logging operation of 1966 indicated that the communities were predominantly a periphyton type composed mainly of diatoms. Immediately following the yarding operation of the clearcut watershed, large quantities of Sphaerotilus natans colonized all debris and mud in the stream. Soon thereafter a change in the algal flora appeared to take place. Large mats of green algae were observed colonizing all mud and slash. Results from glass substrates indicate that some changes may have taken place in the diatom community.

Activity: clearing and tree harvest.

Impact: alteration of natural cover - aquatic vegetation.

Harbo, R.M., and I.K. Birtwell. 1978. Mercury contamination of some marine organisms from Howe Sound, British Columbia. Fish. Mar. Serv. Tech. Rept. 763. 49 pp. (ADF&G, Habitat Library, #B6265.)

This report provides the results of annual surveys carried out from 1970 to 1975 to determine the mercury content of marine organisms in Howe Sound.

Evidence of mercury contamination of marine fishes, invertebrates, and sediments was found in 1970 in upper Howe Sound, British Columbia, adjacent to a chlor-alkali plant utilizing a mercury cell process. As a result, the upper region of Howe Sound was closed to the taking of shellfish, crustaceans, and all fishes except salmon, trout, and herring.

In 1970, up to 9,000 g of mercury were lost daily in effluent from the chlor-alkali plant, but subsequent pollution control measures reduced this daily loss to 40 g.

Rockfishes (Sebastes) spp. and spiny dogfish (Squalus acanthias) had mean mercury contents which were persistently greater than 0.5 ug/g. The mercury content of Sebastes spp. ranged from 0.06 to 1.96 ug/g and in S.acanthias from 0.05 to 2.92 ug/g. In the lingcod mercury contents ranged between 0.02 and 2.11 ug/g.

Crustaceans taken from Howe Sound in 1970 and 1971 had high mercury contents; up to 2.75 ug/g in shrimps and to 13.4 ug/g in Dungeness crabs. However, the mercury content of Dungeness crabs decreased significantly between 1970 and 1975 to a mean level of 0.15 ug/g. It appears that the mercury concentrations in crabs approached normal, or background, levels.

Only a few molluscan samples were analyzed. The mercury content of Pacific oysters ranged from 0.05 to 0.16 ug/g and in blue mussels from 0.02 to 0.70 ug/g.

It is evident that the contamination of some organisms has persisted in spite of the precautions taken to reduce mercury losses from the chlor-alkali plant in Howe Sound. Accordingly the complete removal of the fishing closure cannot be justified, based on these data. (Author's abstract: modified)

Activity: processing minerals; sewage disposal.

Impact: change in levels of heavy metals.

Harr, R.D., and F.M. McCorison. 1979. Initial effects of clearcut logging on size and timing of peak flows in a small watershed in western Oregon. Water Resour. Res. 15(1): 90-94. (ADF&G, Habitat Library, #R3833.)

Size of annual peak flow in a small watershed in Western Oregon was reduced 32%, and average delay of all peak flows was nearly 9 h following clear-cut logging. Size of annual peak flows caused by rain with snowmelt was reduced 36%, and peak flows resulting from rain with snowmelt were delayed an average of nearly 12 h following logging. Changes are attributed mainly to differences in short-term accumulation and melting of snow. No significant changes were detected in size or timing of peak flows that resulted from rainfall alone. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water.

Harr, R.D., W.C. Harper, J.T. Krygier, and F.S. Hsieh. 1975. Changes in storm hydrographs after road building and clear-cutting in the Oregon Coast Range. Water Resourc. Res. 11(3):436-444. (ADF&G, Habitat Library, #R2300.)

Changes in strom hydrographs after road building, clear-cutting, and burning were determined for six small watersheds in the Oregon Coast Range. Peak flows were increased significantly after road building but only when roads occupied at least 12% of the watershed. Roads had no detectable effect on volumes of storm hydrographs. By reducing transpiration and interception, partial clear-cutting increased peak flow, quick flow, delayed flow, and total storm hydrograph volume of some streams. Most increases were largest in the fall when maximum differences in soil water content existed between cut and uncut watersheds. Maximum increases in storm flow occurred after a 175 acre watershed was 82% clear-cut. Here peak flow increased 16 $ft^3/s/mi^2$, quick flow 1.5 in, and total storm hydrograph volume 2.6 in during the fall. The average increase in winter peak flows was smaller. The effect of roads on peak flows has significance for design of culverts in headwater areas or downstream flooding. Caution must be used in extending results of this study to storm runoff events of low frequency and large magnitude. (Authors abstract)

Activity: clearing and tree harvest; grading/plowing; stream crossing - structures.

Impact: change in depth or velocity of water.

Harr, R.D., R.L. Fredriksen, and J. Rothacher. 1979. Changes in streamflow following timber harvest in southwestern Oregon. USDA: Forest Service Res. Pap. PNW-249. 22 pp. (ADF&G, Habitat Library, #B6171.)

Changes in streamflow after complete clear-cutting, small patch clear-cutting, and shelterwood cutting were determined for three small watersheds in southwestern Oregon. The first year increase in annual yield was 36 cm (39%), and increases averaged 29 cm (43%) for 5 yr in a watershed that was completely clear-cut. Increases averaged 6-9 cm (8-14%) in other logged watersheds. Largest absolute increases occurred in winter, whereas largest relative increases generally occurred during fall and summer, when maximum differences in soil water content existed between cut and uncut watersheds. Increases in size of instantaneous peak flow appear related to the proportion of a water-shed where soil had been compacted during logging and slash disposal. Size of peak flow was increased most in the shelterwood cut watershed where soil was compacted on about 13% of the area. Effects of soil disturbance on peak flow may have significance for erosion and for culvert design in headwater areas and for sedimentation downstream but probably are of little importance for flooding of lowlands downstream. Increases in annual water yield under sustained yield forest management will not augment water supplies appreciably in southwestern Oregon. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water.

Harr, R.D., A. Levno, and R. Mersereau. 1982. Streamflow changes after logging 130-year-old Douglas fir in two small watersheds. Water Resour. Res. 18(3):637-644. (ADF&G, Habitat Library, #R3848.)

Timber harvest in two small watersheds in western Oregon containing 130-yr-old timber increased annual water yield up to 42 cm by reducing evapotranspiration. For 4 yr after logging, yield increases averaged 38 cm at a 13.0 ha clear-cut watershed and 20 cm at a 15.4 ha watershed where timber was shelterwood cut. Increased summer flows were indicated by much fewer low-flow days after logging, particularly at the clear-cut watershed. Neither the size nor the timing of peak flows changed significantly after logging at either watershed. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water.

Harris, D.D. 1973. Hydrologic changes after clear-cut logging in a small Oregon coastal watershed. J. Res., USGS (4): 487-491. (ADF&G, Habitat Library, #R3837.)

Preliminary graphical analysis indicates that clear-cut logging of a small Oregon watershed has significantly altered certain hydrologic characteristics. After logging, moderate increases were noted in annual runoff, but no significant changes were detected in either peak or minimum flow rates. Both the annual sediment yields and the maximum monthly water temperatures increased greatly after logging; sediment yields and temperatures in the unlogged control watershed actually decreased during the postlogging period. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Harris, D.D. 1977. Hydrologic changes after logging in two small Oregon coastal watersheds. Geological Survey, Portland, Geological Survey Water-Supply Paper 2037. 31 pp. (ADF&G, Habitat Library, #B6266.)

Effects of clear-cut, cable logging on the hydrologic characteristics of a small coastal stream in Oregon indicate an average 181% increase in sediment yield over a 7-yr postlogging period. Annual runoff and high-flow volumes increased 19 and 1.1 in (480 and 28 mm), respectively, after logging in the watershed. Clear-cutting in small, spaced patches in another watershed resulted in some increase in water and sediment yields, but the increase was not statistically significant. Average monthly April-October maximum water temperatures increased significantly in the principal stream of both the clearcut and "patch-cut" watersheds. Hydrologic characteristics of both streams generally appeared to return to prelogging conditions by 1973. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Harris, J.H. 1981. Study to determine the impact of landward bulkheads or alternative structures on marshes. Summary report, March 1981. Engineering-Science, McLean, Virginia. 106 pp. (ADF&G, Habitat Library, #B6201.)

This report summarizes the final phases of a study, sponsored by National Marine Fisheries Service (NMFS), to examine the effectiveness, in terms of environmental protection, of NMFS' involvement in the U.S. Army Corps of Engineers (COE) dredge and fill permit review process. The study included coastal projects (bulkheads, riprap, gabions, and alternative structures) occurring from Maine to Virginia.

Baseline profiles of preconstruction site conditions and postconstruction impact analyses were developed for various projects. Conclusions of the impact analysis included the following:

1) Placement of riprap landward of fringe marshes rather than further channelward is effective in preserving fringe marshes.

2) Construction of bulkheads landward of fringe marshes was less effective for marsh protection than riprap emplacement landward of marshes, but did result in short term environmental benefits.

3) Realignment of bulkheads to accommodate site-specific environmental features was effective for preservation of fringe marshes and productive bottom habitat.

4) Bulkhead construction at mean high water level is effective in preserving intertidal habitat, but is less effective in protecting immediate channelward marshes, which can become reduced in size due to wave scour against vertical bulkhead faces. (Author's summary: modified)

Activity: filling (aquatic and wetland habitats).

Impact: addition of substrate materials; addition of physical barriers - partial obstructions.

Harrison, S.E. 1975. Factors influencing the acute toxicity of copper sulphate to rainbow trout. Fish. Mar. Serv. Res. Dev. Tech. Rept. No. 573. 6 pp. (ADF&G, Habitat Library, #B6236.)

Experiments were performed to assess the effects of fish weight, photoperiod, temperature acclimation period, and the test solution flow rate on the acute lethality of copper sulfate to rainbow trout (Salmo gairdneri) fingerlings. The median survival time decreased with increasing fish weight; decreased when the test photoperiod differed from the acclimation photoperiod; and increased with increasing temperature acclimation period.

Activity: processing minerals.

Impact: change in levels of heavy metals; change in levels of other toxic compounds - other.

Hartman, A.M. 1978. Mercury feeding schedules: Effects on accumulation, retention, and behavior in trout. Trans. Am. Fish. Soc. 107(2): 369-375. (ADF&G, Habitat Library, #R3885.)

This report presents the results of a study designed to assess the effects of a wide range of dose levels of mercury in feed, as well as intermittent dosing (scheduling). Rainbow trout (Salmo gairdneri) were exposed to 0.5 and 2.0 mg/g doses of ethyl-mercury (p-toluene sulfonanilide) "Ceresan" each day for a full year and 2.5 and 10 mg/g doses delivered every fifth day at feeding time during the year. A further study extended dose levels from 5.0 to 25.0 mg/g Ceresan given daily. Exposure to the lower doses of mercury for either feeding schedule led to concentrations of mercury in muscle that were similar to the average daily index dose for as long as 6 mo of feeding. Assessment of concentration in muscle at 9 mo of feeding showed a breakdown of the effect in all groups except one receiving 0.5 microgram/gram Ceresan daily. Both dose level and schedules influenced the concentrations of mercury in muscle. Daily treatment with higher doses, e.g. 5.0 through 25.0 microgram/gram, led to dose-related concentrations of mercury in muscle, but the regression was greater than one. Orders of mercury concentration in a variety of other tissues differed significantly and were generally dose-related.

Fish receiving 10.0 mg/g of mercury every 5 days or 5.0 mg/g or greater doses every day in their feed were unable, with few exceptions, to learn to avoid shock when preceded by a signal-light. Beyond performance on the learning task, there was no evidence of impairment of general behavior, nor was there any indication of physical debilitation resulting from any treatment. There appeared to be a fairly rapid loss of mercury from selected tissues, although estimates of total body burden of mercury remained high after 6 mo of mercury-free feeding.

Activity: processing minerals; sewage disposal; solid waste disposal.

Impact: change in levels of heavy metals.

Hartman, G.F., and L.B. Holtby. 1982. An overview of some biophysical determinants of fish production and fish population responses to logging in Carnation Creek, British Columbia. Pages 348-372 in G.F. Hartman, ed. Proceedings of the Carnation Creek workshop, a ten year review, 24-26 Feb., 1982. Malaspina College, Nanaimo, B.C. (ADF&G, Habitat Library, #B5050.)

This paper summarizes the initial effects of forest harvesting and management on the important stream processes that are relevant to fish production. The results of the first 11 yr of a 15-yr planned project on the the Carnation Creek watershed provides the base of information. This summary is broken into the following segments concerning 1) temperature regimes, 2) light conditions, 3) nutrient regimes, 4) hydrological regimes, 5) debris conditions, and 6) sedimentation. Further, important salmonid life history stages are tied to each of these stream factors. Finally, management and planning considerations are presented for forest harvest activities.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - aquatic vegetation; change in levels of nutrients.

Hartman, G.F., and R.M. Leahy. 1983. Some temperature characteristics of stream and intra-gravel water in Carnation Creek, British Columbia. Can. MS. Rep. Fish. Aquat. Sci.: 1731:iv + 36 pp. (ADF&G, Habitat Library, #B5296.)

Twenty series of measurements of stream and intragravel water temperatures were made in Carnation Creek above the zone of tidal influence during a 1-yr period. Four series were made in the part of the stream that was within the zone of tidal influence. Intragravel temperatures within a series were more variable than those of the stream and tended to be lower than those of the stream in summer and higher in winter. In several of the series of measurements taken during the summer, stream temperatures were relatively low in the areas where the intragravel temperatures were low. In such temperature series taken in summer, stream temperatures were progressively lower from upstream, at such sites, to downstream. During a series of measurements taken in winter and early spring, the stream appeared to warm along the length within the reach where temperatures were taken. In the zone of tidal influence, summer intragravel temperatures, apparently influenced by warm incoming tide water, were higher than those of the stream.

This paper discusses the fact that measurements of stream temperatures at specific sites may not indicate very well what the intragravel temperatures, at egg incubation depth, may be. Where artificial egg introductions are made and there is a desire to know or control the time of emergence this should be kept in mind. Secondly, the paper discusses the fact that during summer, in a clear-cut area of the stream, water temperatures become progressively lower downstream. The fact that this may occur in some situations should be recognized by fisheries people, evaluating forest harvest impacts. (Authors abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature.

Hartman, G.F., B.C. Andersen, and J.C. Scrivener. 1982. Seaward movement of coho salmon (<u>Oncorhynchus kisutch</u>) fry in Carnation Creek, an unstable coastal stream in British Columbia. Can. J. Fish. Aquat. Sci. 39: 588 - 597. (ADF&G, Habitat Library, #R3178.)

The seaward movement of coho (<u>Oncorhynchus kisutch</u>) fry was monitored over a 10-yr period as a part of a major watershed study. The time period over which downstream movement took place varied widely during different years of study. Coho fry moved seaward earlier, and terminated the main period of movement earlier, following winters in which stream temperatures were warmer. It is presumed that they underwent more rapid development during winters in which stream temperatures were relatively high. Winter stream temperatures were primarily dependent on air temperatures. During seaward movement daily numbers fluctuated widely. Peaks of movement were coincident with or slightly before freshet peaks. In 94 of 122 cases (77%), the number of fry moving seaward during the night of peak discharge or during the night before was higher than in any of the three preceding nights. Movement in these cases may have been initiated by rainfall or falling water temperature or a combination of both. Aggressive behavior among coho fry is considered to be an underlying cause of seaward movement. In Carnation Creek, particularly in the early part of the period of seaward movement, the effects of such social behavior on movement patterns may be masked by the effect of freshets and related conditions. By autumn the number of fry remaining in the stream ranged from 9,000 to 13,000 over the 10-yr study. Much of the downward adjustment to this resident fry population size occurred after the most active period of seaward movement. (Authors abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in depth or velocity of water.

Hartman, G.F., J.C. Scrivener, M.J. Brownlee, and D.C. Morrison. 1983. Fish habitat protection and planning for forest harvesting in coastal streams of British Columbia: some research and management implications. Can. Ind. Rept. Fish. Aquat. Sci. 143. 73 pp. (ADF&G, Habitat Library, #B1182.)

The first of the two parts of this report reviews some of the major results emerging from the Carnation Creek Watershed Study. The paper considers the implication of research results of the British Columbia Coast Forest Planning Guidelines and Protection Clauses. The second part of this report reviews those salient elements, of the stream protections clauses used for coastal streams in British Columbia, outlines the purpose of the elements and suggests areas for revision. The appendices include copies of the protection clauses and related management correspondence. This annotation includes only part one of this report.

The authors point out two important generalizations that can be made about the nature of population regulation and the impacts of logging on salmon and trout. The first is energy-related, and the second is habitat-related.

Opening the canopy over the stream tended to improve the rate of energy introduction to and transfer through the biological community in the stream. As a result, microbial respiration, total primary production, densities of benthos, drift of food organisms, and growth and densities of predators, including salmonids can all increase. These impacts are the result of increased light penetration, water temperatures, and dissolved nutrients in the stream. This can be most pronounced in streams like Carnation Creek, which in their pristine state are cold, heavily shaded, flashy, and oligotrophic. These positive impacts are less pronounced or can be detrimental impacts for streams in which temperatures and nutrient loads are initially higher. As revegetation and second-growth forest develops, nutrient loading and direct energy inputs rapidly decline.

Watershed and streamside disturbance tended to generate a spectrum of physical habitat changes that produced negative impacts on the biological community in the stream. Streamside disturbance destabilized or broke up large organic debris. As a result, channel and bed morphology changed extensively during major freshets. Stream banks were eroded, and suspended sediment and bed load movement increased. As a result, salmonid egg-to-fry survival and benthic food organism densities declined in the gravel. Coho fry densities also declined within the stream reaches that were affected. These changes did not begin until 2 yr after the initiation of logging. In low-gradient, flashy, and boulderless streams like Carnation Creek, large woody debris maintains the stability of riffles and pools, armors the banks, and forms the necessary fish cover. The time frame for mitigation of these kinds of changes is much longer than for those that are energy related. (Author's synopsis)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; change in levels of nutrients.

Hartman, G.F., L.B. Holtby, and J.C. Scrivener. 1984. Some effects of natural and logging-related winter stream temperature changes on the early life history of coho salmon (Oncorhynchus kisutch) in Carnation Creek, British Columbia. Pages 141-149 in W.R. Meehan, T.R. Merrell Jr., and T.A. Hanley, eds Proceedings of a symposium, fish and wildlfie relationships in old-growth forests. Juneau, Alaska, 12-15 April, 1982. (ADF&G, Habitat Library, #R5083.)

This paper deals with some of the effects of natural and logging-induced stream temperature changes in winter on juvenile coho salmon. Extensive logging began in the winter of 1976-1977 and continued until 1980-1981, by which time 41% of the watershed had been clear-cut. Stream temperatures in early winter from 1976-1977 through 1980-1981 were higher than they had been prior to logging. Temperature increases resulted from climatic amelioration, which began in 1976, and from the effects of logging. As a result of higher temperatures, coho salmon fry emerged earlier in the spring than they had prior to logging. Early emergent fish that did not move downstream during spring freshets began growing sooner. In 1981, the year of highest winter temperatures, fry emerged 47 d earlier than in the prelogging years and this, coupled with faster growth in late spring, led to the fish entering their first winter at a larger size. Consequently, survival through the winter was greater, leading to increased numbers and size of 1-yr smolts and an increased proportion of 1-yr versus 2-yr smolts. Brief speculation is offered about processes that may have affected stream temperatures during winter. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature.

Hartmann, J. 1983. Char as indicators of pollution. Fisheries 8(6):10-12. (ADF&G, Habitat Library, #R3886.)

Information obtained through literature review and field surveys for Lake Constance, Norway, have led the author of this paper to conclude that arctic char (Salvelinus salvelinus) can be used as an indicator organism for determining the relative state of pollution under certain conditions. Surveys of water quality on the lake indicate that char populations are concentrated in areas of the lake where degradation of water quality has been least noticeable. Because char are not selective feeders and because other associations could not be found that would explain the shift in char populations during the 1960's and 1970's (a period when the lake was in a transition from an oligotrophic to a mesotrophic condition), the author concluded that the shift in distribution was probably the result of changes in water quality.

Activity: sewage disposal.

Impact: change in turbidity or suspended sediments; change in levels of heavy metals; change in levels of hydrocarbons; change in levels of nutrients.

Hartwick, E.B., R.S.S. Wu, and D.B. Parker. 1982. Effects of a crude oil and an oil dispersant (Corexit 9527) on populations of the little neck clam (Protothaca staminea). Mar. Environ. Res. 6:291-306. (ADF&G, Habitat Library, #R3899.)

Laboratory experiments and field experiments on Vancouver Island were carried out to investigate the effects of Alberta crude oil and an oil dispersant (Corexit 9527) on the larval settlement, survival, siphon activities, and behaviour of the littleneck clam (Protothaca staminea). Corexit 9527 was much more toxic than crude oil, and the highest toxicity was obtained when Corexit 9527 was mixed with crude oil. Siphon activities were impaired, and abnormal behaviour was exhibited when adult clams were treated with 100 ppm Corexit 9527, 1,000 ppm crude oil, or a combination of both. Larval settlement was not affected when the substratum was treated with a mixture of 1,000 ppm oil and 100 ppm Corexit 9527. Gas chromatograms also showed that the retention time and depth of penetration of hydrocarbons in the substratum was increased when Corexit 9527 was used with crude oil.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Harvey, B.C., K. McCleneghan, J.D. Linn, and C.L. Langley. 1982. Some physical and biological effects of suction dredge mining. California Department of Fish and Game, Lab. Rept. No 82-3. 20 pp. plus appendices. (ADF&G, Habitat Library, #R2729.)

Studies on three streams examined the effects of suction dredge mining on the water quality parameters of turbidity, settleable solids, and sedimentation rate, as well as the effects on populations of aquatic insects and fish. These studies included documentation of effects from a single dredge and investigation of additive effects from numerous dredges along a stream reach. The area most impacted was from the dredge site to about 30 m downstream. The size of the impact zone depended on the size of the dredge (those studied in this work had pick-up hoses 6 in in diameter) and stream substrate composition.

Fish densities were very low before dredging activity commenced. Therefore, little or no change was detectable in the fish populations over the course of the study, except that sculpin populations declined by 50% below dredges because of reduction of suitable habitat.

Alteration of stream substrate also caused the benthic insect species to decline.

No additive effects were detected on streams where a number of dredges were being operated.

Activity: dredging; processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Hasfurther, V.R. 1985. Use of meander parameters in restoring hydrologic balance to reclaimed stream beds. Pages 21-40 in J.A. Gore, ed. The restoration of rivers and streams: theories and experience. Butterworth Publ., Soneham MA. (ADF&G, Habitat Library, #R5150.)

This chapter discusses methods and techniques for restoring a stream channel to its natural inclinations after a human-induced change such as surface mining, road construction, etc. The main emphasis will be on meander parameters and their importance in stream channel stability.

In spite of the complexity of a stream system, the same basic factors govern the delicate balance of all streams. It is important that stream managers understand and work with these basic natural factors that govern the stream system. These natural factors are 1) geologic, 2) hydrologic, 3) hydraulic, and 4) geometric. Together, these factors interact to develop the stream system.

Geologic factors. Geologic factors influence the nature and amount of sediment production and the development of meanders due to topography and soil conditions. Topography determines overall slope of the area and can be a limiting factor in meander formation as a result of the location of large relief areas (hills) that will automatically change the direction of the stream channel. The abruptness and amount of change will be a characteristic of the soil material. The amount of sediment production will also depend upon the type of soil and general slope of the stream channel.

Hydrologic factors. Hydrologic factors will influence the variations in flow and runoff and thus the type of meander system developed by the stream. Long-term climatic flucutations can cause variations in runoff that can cause major changes in a stream's morphology. Along with the soil conditions, the amount and type of vegetation on the landscape will have a great influence on runoff and associated infiltration characteristics.

Hydraulic factors. Hydraulic factors include depth, slope, and velocity of a stream. These factors are the characteristics that directly produce bank cutting, sediment transport, and the like. Hydraulic factors tend to change channel cross-sectional shape, pool and riffle formation, and meander shape.

The hydraulics of flow in streams is complex. Some of the major compilications are a) the large number of interrelated variables (depth, slope, and velocity) in describing the response of natural or imposed changes to the stream system and b) the continual change of stream patterns and channel geometry with changes in flow and sediment discharge. By changing the slope of a stream, it is possible to change a stream from a fairly stable situation (meandering stream) that has fairly tranquil flow to an unstable situation (braided stream, very dynamic) that has high velocities and carries large quantities of sediment.

Geometric factors. Geometric factors consist of the channel cross-sectional shape, stream pattern (straight, meandering, or braided), and the pool-riffle pattern that may exist on smaller streams. On many alluvial-type streams, significantly different channel dimensions, shape, and patterns are associated with amount of discharge and sediment load, indicating that changes in these variables can cause significant adjustments to the goemetric factors.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

Hastings, R.W. 1972. The origin and seasonality of the fish fauna on a new jetty in the northeastern Gulf of Mexico. Ph.D. Thesis, Florida State Univ., Tallahassee, FL. 555 pp. (ADF&G, Habitat Library, #R3955.)

The establishment of the fish fauna on a new jetty at East Pass at the mouth of Choctawhatchee Bay, Okaloosa County, Florida, was studied during the period from June 1968 to January 1971. Both successional and seasonal changes occurring in the fish fauna were analyzed and compared with observations on older reef habitats in the northeastern Gulf of Mexico, such as jetties at St. Andrew Bay, Bay County, Florida, and also several natural reefs offshore at depths of 18 to 30 m.

Each habitat is described and chemical and physical parameters that might affect the fish faunas are reviewed. Variations in salinity, water clarity, currents, surge, and depth (in addition to temperature) must have affected the fish fauna on the jetties. Salinity, water clarity, and currents fluctuated with the tidal cycle. Low-salinity bay water tended to circulate along the channel side of the jetty during the ebb tide, causing salinity differentials as high as 15 ppt across an isocline at about one m depth. By the end of a flood tide, however, the salinity on each side of the jetty was about equal. Thus fishes on the channel side of the jetty were subjected to a wide range of salinities daily.

Water clarity was also affected by the tidal cycle since the ebbing bay water was more discolored than the high-salinity gulf water. Consequently, the water on the channel side was generally less clear and also varied to a greater extent than that on the gulf side. Tidal flow along the jetty often created strong currents on the channel side but rarely on the gulf side.

Differing water depths on the jetties also affected species abundance and diversity. More available cover and deeper water areas tended to increase the number of fish present.

Seasonal changes in the fish fauna at the jetties were pronounced. The major autumn decline in the number of species inshore occurred in November at a temperature of about 20°C. Only about 5 to 10 species were usually counted during the winter months. The spring increase began during Fegruary or March at temperatures of about 15 to 20°C.

A total of 199 species were recorded at the East Pass and St. Andrew jetties; at least 150 species were common to both habitats. (Author's abstract: modified)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; addition of physical barriers - partial obstructions; change in level of salinity.

Hathaway, C.B. 1978. Stream channel modification in Hawaii. Part C: tolerance of native stream species to observed levels of environmental variability. USDI: USFWS. FWS/OBS-78-18. 59 pp. (ADF&G, Habitat Library, #B6557.)

Streams in Hawaii have been subjected to water diversion, exotic introductions, and several forms of channelization. The latter have included realignment, clearing of riparian vegetation, and construction of artificial bank and bed structures. Channel modification has been correlated with increases in physico-chemical variability and reductions in numbers of several endemicgobiid fishes in altered streams. The amphidromous migratory behavior of the native fauna prevents the isolation of any species from the effects of channelization on water quality.

Daytime values of conductivity, pH, and dissolved oxygen were found to be considerably higher in altered streams than in unaltered streams. Temperature was monitored weekly for 1 yr at 20 stations to assess the relative effects of different channel types on thermal fluctuations. All stations located downstream from channel modifications had higher diurnal peak temperatures than upstream and unaltered stream stations. Temperature extremes of 36.2 and 17.8°C were recorded at the downstream end of a concrete-lined channel. Diel changes in temperature of 12°C were not uncommon at this site. High illumination due to clearing of the vegetative canopy and shallow water depths in lined channels appear to be responsible for the excessive heating.

Tolerances of native species and key exotics to elevated temperatures were determined using a gradual heating method designed to simulate in situ diurnal heating. Growth of postlarval migrating forms of several gobiids was measured following 1 mo exposures to different fluctuating thermal regimes. Upper lethal temperatures correlated with altitudinal distributions of adult fishes and crustaceans. Lethal limits of those species absent or rare in altered streams fell within the range of temperatures recorded in such degraded habitats. Dominant introduced fishes showed greater resistence to high temperatures than native animals. Maximum growth rates occurred in fluctuating temperatures whose diel maxima were 7-8°C below upper lethal limits.

Where future channel modification cannot be avoided, channelized sections should be kept as short as possible, with natural sections interspersed between them along the length of the stream. Near-stream vegetation should be maintained. Lined channels should contain V-shaped notches at mid channel or a slanting bottom in order to maximize depth during low-flow conditions. Mitigation for existing channels should include revegetation of stream banks. (Author's summary)

Activity: channelizing waterways.

Impact: change in water temperature; alteration of natural cover - riparian vegetation; addition of physical barriers - diversions; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness; introduction or removal of species.

Hausle, D.A., and D.W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout (Salvelinus fontinalis). Trans. Am. Fish. Soc., 1976, 1:57-63. (ADF&G, Habitat Library, #R2783.)

Alevins of brook trout were buried in laboratory troughs in spawning gravel containing 0 to 25% sand (less than 2 mm diameter). Sand slowed emergence and reduced the number of fry emerging. Weight of fry was not related to proportion of sand in the gravel but was related to time; the fry were heaviest near the time of peak emergence and lighter before and after the peak.

Activity: clearing and tree harvest; dredging; grading/plowing.

Impact: change in turbidity or suspended sediments.

Hawkins, A.D. 1973. The sensitivity of fish to sounds. Oceanogr. Mar. Biol., Ann. Rev. 11:291-340. (ADF&G, Habitat Library, #R3253.)

In this review of experimental studies, the author concludes that the sensitivity to sounds of many teleost fish is acute at low frequencies and that only species in which the swim bladder is closely linked with the ear show a range extending to relatively high frequencies. Most fish examined have shown a very pronounced decline in sensitivity at their upper frequency limit, which apparently prevents them from detecting the higher frequency components of many natural sounds (e.g., high-frequency signals emitted by cetaceans). At low frequencies, fish have generally shown a more gradual decline in sensitivity. The significance of this difference in sensitivity at low and high frequencies has not been determined.

In experiments to elicit avoidance responses from fish, the usual response of a fish to sounds is a quick movement or startle response. These startle reactions are often very brief and the fish appear to adjust to higher sound levels. Fish were observed diving in response to a high intermittent sound, but in these experiments, also, the fish adjusted to the noise. There is evidence that fish respond to the sound produced by fishing gear and certain types of trawling gear may be more efficient because of the low-frequency vibration of the cables.

Although different sounds have succeeded in attracting predatory species of both elasmobranchs and teleosts, the mechanism by which these fish reach the source is not fully known. Also, it is not known whether or not fish use hearing abilities to actively seek prey or to avoid predators.

Activity: blasting; drilling; human disturbance; netting.

Impact: increase in hydrostatic pressure or noise; artificial attractant to biological organisms.

Haywood, G.P. 1983. Ammonia toxicity in teleost fishes: a review. Can. Tech. Rept. Fish. Aquat. Sci. 1177. 35 pp. (ADF&G, Habitat Library, #B6234.)

Previous literature concerning ammonia toxicity to teleost fishes is reviewed, and the manner is examined in which factors such as temperature, pH, carbon dioxide, dissolved oxygen, and dissolved solute affect the un-ionized ammonia fraction. Some interpretations are suggested concerning the observable symptoms and possible physiological action of ammonia toxicity. A table of previous findings regarding ammonia toxicity to a number of teleost species is presented, and units are standarized. From these findings the maximal permissible (safe) levels of un-ionized ammonia in polluted waters are suggested as 2 ug/l for salmonids, 10 ug/l for other freshwater teleosts, and 50 ug/l for other seawater teleosts. The corresponding maximum levels for total ammonia are suggested as 1, 2.5 and 2.5 mg/l, respectively. (Author's abstract)

Activity: channelizing waterways; sewage disposal.

Impact: change in levels of other toxic compounds - other.

Heckman, C.W. 1984. Effects of dike construction on the wetland ecosystem along the freshwater section of the Elbe Estuary. Arch. Hydrobiol., Suppl. No. 61. (ADF&G, Habitat Library, #R3659.)

Since the completion of a new dike in 1978, a large portion of the Haseldorfer Marsh, an alluvial wetland region along the freshwater section of the Elbe Estuary, has been cut off from tidal influence. The structure of the biotic community in the former tidal channels was observed to be undergoing fundamental changes. A survey of the local distribution of more than 900 species revealed that the species diversity of the aquatic biota behind the new dike is increasing but that a number of species endemic to the North Sea estuaries and their supralittoral zones are rapidly disappearing and may eventually face extinction if the rest of their habitat is drastically modified. Along with the biotic changes, the chemical parameters in the water behind the dike have undergone significant alteration. A small sluice gate that is sometimes opened to allow water to pass through the dike has little effect on the ecological developments, except when it is operated to almost fully drain the wetlands. The flood plain wetlands formerly acted as depositories and sites of decomposition for suspended matter in the estuary. The dike has thus detracted from the self-cleansing capacity of the Elbe. In contrast to the aquatic biota, the terrestrial flora and fauna have become impoverished behind the dike because of landscaping projects and heavy grazing by sheep. (Author's Abstract).

Activity: filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions; change in levels of nutrients.

Heiser, D.W., and E.L. Finn. 1970. Observations of juvenile chum and pink salmon in marina and bulkheaded areas. State of Washington, Dept. Fisheries, Management and Research Division. Supplemental progress report, Puget Sound Stream Studies. (ADF&G, Habitat Library, #R0502.)

Marinas, bulkheads, and breakwaters were evaluated to determine their effects on feeding and migrating of pink and chum salmon fry. Increased predation by cottids, coho smolts, and cutthroat trout has been noted when pink and chum fry are forced to move into deep water to go around a bulkhead or breakwater leaving the shallow shoreline areas. Visual observations indicated that predation on salmon fry within marinas was minor because the human and boat activities discouraged predators from attacking salmon fry. Very small 34-45-mm salmon fry would not go out into deeper water to go around bulkheads and were concentrated in large numbers, making an ideal situation for predators. Vertical bulkhead designs were the most disruptive to salmon fry migration. Desirable designs included riprap or natural material placed at an angle of 45 or less, providing protective habitat for young salmon.

Activity: filling (aquatic and wetland habitats); human disturbance; transport personnel/equipment/material - water.

Impact: addition of substrate materials; addition of physical barriers - partial obstructions; increase in hydrostatic pressure or noise; change in level of dissolved oxygen, nitrogen.

Heming, T.A. 1982. Effects of temperature on utilization of yolk by chinook salmon (Oncorhynchus tshawytscha) eggs and alevins. Can. J. Fish. Aquat. Sci. 39:184-190. (ADF&G, Habitat Library, #R3608.)

Growth, development, and survival of chinook salmon during the yolk absorption period (fertilization to complete yolk absorption) were examined at 6, 8, 10, and 12°C. Higher rearing temperatures reduced both the duration of the yolk absorption period and the overall amount of energy available for tissue growth during that period. Salmon encountered a metabolic energy deficit before yolk reserves were exhausted; tissues were resorbed during absorption of the last 10 mg (dry weight) of yolk. Salmon held above 10°C experienced reduced survival, hatched and emerged precociously, and were smaller at hatching, at emergence, at maximum tissue weight and at complete yolk absorption than fish at lower temperatures. (Author's abstract: modified)

Activity: clearing and tree harvest; grazing; water regulation/withdrawal/irrigation.

Impact: change in water temperature.

Heming, T.A., J.E. McInerney, and D.F. Alderdice. 1982. Effect of temperature on initial feeding in alevins of chinook salmon (Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 39:1554-1562. (ADF&G, Habitat Library, #R3580.)

Growth and survival of chinook salmon during the transition to active feeding were examined in relation to the timing of initial food presentation at 6, 8, 10, and 12°C. The transition to active feeding in these salmon involved a period of "precocious feeding" during which ingestion of food had no effect on fish size, growth rate, or survival. Initial utilization of food for growth and survival did not coincide with any specific stage of development, but rather it occurred earlier and at a less mature stage of development at higher temperatures. Delays in initial food presentation beyond this point reduced fish size and survival. Temperature and the timing of initial food presentation interacted to create a zone of optimum feeding. Biomass production was maximized when alevins began to feed within this zone, independently of the precise time of initial food presentation or temperature. This optimum feeding zone existed at temperatures below 12°C, between 905 thermal units (TU) postfertilization and a point (F, TU) that varied with temperature (T, °C) as F = 1201.1 - 20.3T. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing; grazing; processing minerals; water regulation/withdrawal/irrigation.

Impact: change in water temperature.

Hendrick, M.R. 1976. Effects of stream channelization on fish populations in the Buena Vista Marsh, Portage County, Wisconsin. (ADF&G, Habitat Library, #B1969.)

Fish populations from ditches 6-8 yr old and 52-62 yr old within the Portage County Drainage District were compared with populations in adjacent portions of natural streams. Two study areas were selected: an upstream zone of good brook trout (Salvelimus fontinalis) habitat and a downstream zone in marginal trout waters where white sucker (Catostomus commersoni) were numerous. Each area included new ditch, old ditch, and natural stream, all of similar discharge. Estimates of annual production of brook trout, population and biomass of brook trout and white sucker, and total catch records for other fish species were derived from electrofishing samples in June, August, and September, 1974, and April-May, July and September, 1975. A creel survey was conducted during the 1975 trout season.

Loss of year-round in-stream cover through channelization limited brook trout density, which reduced annual production of brook trout to 28.8 kg/stream km in the upstream new ditch study area compared to 72.2 kg/km in the upstream old ditch and 65.5 kg/km in the upstream natural stream. Angler success was also reduced, from 1.03 trout/hr in the upstream old ditch and 1.05 trout/hr in the upstream natural stream to 0.26 trout/hr in the upstream new ditch. Midsummer water temperatures reached upper lethal levels for brook trout in the downstream ditches, where current velocity was reduced and white sucker were abundant. Mottled sculpin (Cottus bairdi) were consistently absent from the upstream new ditch and scarce in the downstream new ditch. The natural stream had the greatest number of fish species in both study areas (12 upstream and 18 downstream), and the new ditch has the fewest (9 upstream and 11 downstream). (Author's abstract)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; alteration of natural cover - aquatic vegetation; introduction or removal of species.

Henegar, D.L., and K.W. Harmon. 1971. A review of references to channelization and its environmental impact. In E.Schneberger and J.L. Junk, eds. Stream channelization: a symposium. Special Publ. No. 2. North-central Division, Am. Fish., Soc., Omaha, Nebraska. (ADF&G, Habitat Library, #R5148.)

Brief annotated references are given for downstream flooding, drainage outlets, sediment damage, groundwater recharge, and fishery and wildlife losses. There are a total of 63 references included.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - diversions; introduction or removal of species.

Hess, S. 1984. Timber harvesting and flooding. J. Soil Water Conserv. 39(2): 115-117. (ADF&G, Habitat Library, #R3847.)

This short paper presents results from a study conducted on Cabin Creek, a tributary of the Yakima River in Washington. The evaluation of flooding in Cabin Creek watershed produced observations important to the relationships between timber removal, flow regimes, and changes in channel conditions:

1) Severe channel erosion occurred as a result of extremely high flows produced by major rain-on-snow storms.

2) Management activities in the Cabin Creek watershed have been fairly consistent since timber management began in 1958. There was no apparent relationship between channel erosion and the percentage of upstream timber that had been removed.

3) Debris torrents from tributary streams in the Cabin Creek watershed could all be traced to mass failures on adjacent slopes. These mass failures came from roads, clearcuts, and undisturbed areas. Mobile organic debris accounted for much of the flood damage that occurred.

(Author's conclusions: partial)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water.

Hesse, L.W., and B.A. Newcomb. 1982. Effects of flushing Spencer hydro on water quality, fish and insect fauna in the Niobrara River, Nebraska. N. Am. J. Fish. Manage. 2:45-52. (ADF&G, Habitat Library, #R3016.)

The water reservoir impounded by the Spencer Dam, a hydroelectric facility in northern Nebraska, is shallow and is filled relatively quickly by entrapped sediment. Periodic flushings are necessary to maintain peak generating efficiency; these flushings were found to have adverse impacts on water quality, fish, and fish-food organisms in the Niobrara River downstream from the dam. Investigations in 1979 showed low levels of dissolved oxygen (3.5-4.0 mg/l), increases in turbidity (greater than 400%) and suspended solids (4-fold), and a doubling of dissolved solids. Although only 2 of the 30 species of fish, northern pike and brown trout, that were found most impacted (die-offs), are found in Alaska, the diversity of impacted fish species listed in this paper suggests the stress imposed by periodic flushing of collected sediments from a small pond. Young fish were most affected. Large changes in the abundance of many species of immature aquatic insects are also reported.

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness.

Hill, A.R. 1976. The environmental impacts of agricultural land drainage. J. Environ. Manage. 4:251-274. (ADF&G, Habitat Library, #R5126.)

Agricultural land drainage, which includes the construction of ditches and the channelization of water courses, as well as field underdrainage, can have a variety of effects on the environment. The draining of marshes and other types of wetland produces alterations in plant and animal communities. A reduction in wetland acreage can also affect streams and lakes by causing changes in water quality and hydrology. The construction of ditches and channelization of natural streams has a direct local impact on flora and fauna in and adjacent to the water course. Ditching and field underdrainage systems may also produce downstream effects over considerably areas, involving alterations in hydrology, channel form, sediment load, water temperature, chemistry and aquatic biology. Many of the environmental impacts of land drainage are imperfectly understood. Research is urgently required in order to establish more clearly the frequency and magnitude of these environmental effects. This information will provide a better basis for the design and implementation of drainage schemes. (Author's abstract)

Activity: channelizing waterways; draining.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; change in levels of nutrients.

Hill, S.H. 1978. A guide to the effects of underwater shock waves on arctic marine mammals and fish. Inst. Ocean Sciences, Sidney, B.C. Pac. Mar. Sci. Rept. 78-26. 50 pp. (ADF&G, Habitat Library, #R0514.)

Damage to salmon from underwater dynamite explosions is concentrated in the organs and tissues near the gas bladder. Internal damage includes ruptured gas bladder, kidney, gonads, and spleen; ribs were torn loose from the body wall, and there was torn adipose tissue and burst blood vessels in the body wall. The fish's orientation relative to the shock wave's direction of travel has a significant effect on the damage sustained. Fish struck from the ventral or lateral directions suffered more damage than those struck from the head-on or tail-on directions. Most of the fish not killed immediately in an explosion will be disabled and more vulnerable to predation.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Hirsch, N.D., L.H. DiSalvo, and R. Peddicord. 1978. Effects of dredging and disposal on aquatic organisms. U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss. Tech. Rept. DS-78-5. 41 pp. (ADF&G, Habitat Library, #B5312.)

This study evaluated the effects of dredging and disposal on the physical disruption of the bottom sediments, the generation of suspended sediments, and the contaminant load of the sediments being disturbed and redistributed. The presence of organisms and the species' diversity are major variables at different dredging and disposal sites.

Direct effects of dredging include removal of the established community and creation of a new substrate, which may or may not resemble the original sediments. The recovery time at disturbed sites varies; for more naturally variable environments it is rapid. Many sediment-dwelling animals move vertically, and if the dredged material is similar to the natural sediments, this vertical migration will be unaffected.

Turbidity from dredging may affect functions such as photosynthesis, but this impact is transitory. The sediment suspension near the bottom known as "fluid mud" or "flucculent layer formation" is more serious than turbidity. Fluid muds are an extreme stress to bottom environments because they are usually low in dissolved oxygen, and they may last for weeks before they become consolidated. Fluid muds can have direct adverse effects on adult macrofauna, as well as indirect effects where they form a blanket over fish-spawning grounds and areas critical in juvenile life stages.

Results of the research show that dredged material is not as toxic to aquatic organisms as originally believed. Bioaccumulation by itself is difficult to interpret in terms of toxicity. Accumulation may stress the organism and make it more susceptible to disease or predation. Necessary energy may be diverted into detoxification mechanisms. Lowered fecundity and abnormal larval development will ultimately have effects on species abundance and population dynamics. Sublethal effects can result in an unexplained population decline over an extended time period.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in levels of heavy metals; change in levels of other toxic compounds - other; change in levels of hydrocarbons.

Hoff, J.T., J.A.J. Thompson, and C.S. Wong. 1982. Heavy metal release from mine tailings into sea water - a laboratory study. Mar. Pollut. Bull. 13:283-286. (ADF&G, Habitat Library, #R3917.)

In a laboratory experiment to simulate mine-tailings disposal into a coastal inlet of British Columbia, initial rapid increase in dissolved iron, copper, and lead were observed in the first 3 h, with subsequent slow decrease to background values within 1 mo. Manganese and nickel increased slowly during the experiment, while cadmium and zinc did not increase. The major environmental concerns of marine disposal of mine tailings are the smothering of benthic habitats, the possible exposure of the marine food web to sublethal concentrations of metals, and an overall effect such activities may have upon commercial fisheries. The results indicate that the release of metals is dependent upon tailings concentration and that the removal of metal is not thus dependent. A high flushing rate and vigorous tidal exchange may prevent a build-up of dissolved metals in the water column.

Activity: solid waste disposal.

Impact: change in levels of heavy metals.

Hok, J.R. 1969. A reconnaissance of tractor trails and related phenomena on the North Slope of Alaska. USDI: BLM. 66 pp. (ADF&G, Habitat Library, #B0120.)

This report emphasizes the long-lasting effects of the movements of vehicles across or operations in the tundra-permafrost environment of the North Slope of Alaska. The use of heavy tracked vehicles (particularly caterpillartype vehicles, as opposed to broad-tracked, light personnel carriers like the "weasel" or "bombardier") often resulted in marked changes of disturbed surfaces. These changes were consistent with reference to four major variables:

1. the season (frozen vs. thawed ground) during which the disturbance took place;

2. the degree to which surface material had been bladed aside;

3. the water content of the substrate (ice-rich v. well-drained);

4. and the degree of slope.

The most important variable in determining what changes will occur in the path of a heavy tracked vehicle is the season. Surface movement during the summer months produced closely related disturbances that link the second, third, and fourth variables.

Activity: transport of oil/gas/water - land; transport personnel/equipment/material - land.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation.

Holtby, L.B., and G.F. Hartman. 1982. The population dynamics of coho salmon (Oncorhynchus kisutch) in a west coast rain forest stream subjected to logging. Pages 308-347 in G.F. Hartman, ed. Proceedings of the Carnation Creek workshop, a ten year review, 24-26 Feb., 1982, Malaspina College, Nanaimo, B.C. (ADF&G, Habitat Library, #R5086.)

This paper analyses the factors which regulate the in-stream population dynamics of coho salmon, as related to the logging-induced watershed impacts. The authors provide two primary conclusions. First, the growth and survival of juvenile coho salmon are food-limited in Carnation Creek. Stream productivity in the prelogging state was probably limited by a combination of low light, low temperatures, and low nutrient availability. Stream production ultimately determines the availability of food to stream fishes. Evidence that food limits of coho growth and survival come from the density dependence of growth and survival and the nature of other system variables that are predictive of growth or survival, the negative effects of low flows, the positive effects of streamside harvest, the positive effects of increased temperatures, etc., can all be related to food production or food delivery rates. Second, winter mortality rates of juvenile coho salmon in Carnation Creek account for approximately 51% of the total mortality observed over the one or two years of stream residence. The severe winter flow regime of the creek is, in large part, responsible for the high mortalities. In addition, because winter mortality is dependent on fish size, mortality is strongly affected by growth conditions during the previous summer. Consequently, logging-related impacts on summer conditions have ramifications to late life stages.

Removal of the forest canopy through clear-cut logging has resulted in increased stream surface light levels, higher stream temperatures, and probably higher nutrient availability, all of which have led to increased stream productivity. The juvenile coho have shown a marked response to this presumed increase in stream productivity and stream temperatures. Higher winter temperatures since logging have caused earlier emergence of fry, resulting in a prolongation of the growing season. Higher growth rates in the postemergence period and over the first summer have increased the size of yearling coho entering their first winter, and lower summer mortalities have increased the numbers of yearlings entering the first winter. More large fish entering the winter have increased winter survival, resulting in greater numbers of large smolts leaving the creek at an earlier age. Two years later, more adults return. These positive effects of logging are, in all probability, transitory. Stream productivity can be expected to return to near prelogging levels within 12 to 15 yr.

Streamside logging has led to gradual but accelerating changes in stream morphometry. Sedimentation and bedload movement associated with bank erosion and channelization have resulted from streambank logging practices and debris transport caused by logging activity. Such habitat degradation is implicated in already declining egg-to-fry survival. Continued degradation of habitat quality will eventually compromise the capacity of the creek to support overwinter survival. Further long-term damage to the productive capacity of Carnation Creek could result from the reduction or elimination of the supply of large organic debris. (Authors summary: modified)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; change in levels of nutrients.

Houghton, J.P., and D.L. Beyer. 1980. Effects of oil well drilling fluids on several important Alaskan marine organisms. Pages 1,017-1,043 _in_ American Petroleum Institute, comp. Research on environmental fate and effects of drilling fluids and cuttings. Symposium Proceedings: Vol. 2; Jan. 21-24 1980; Lake Buena Vista, Florida. 1,122 pp. (ADF&G, Habitat Library, #B4291.)

The tolerances of seven indigenous organisms (pink salmon, pandalid shrimp, mysids, isopods, staghorn sculpins, and mussels) to solutions of drilling fluids taken from the lower Cook Inlet (Continental Offshore Stratigraphic Test) well, using static, acute, 48- and 96-h bioassays were examined. Toxicity of drilling fluids was generally low, with 96-hour 50% mortality (LC50) values ranging from 3,000 ppm for pink salmon to greater than 100,000 ppm for shrimp. In addition, _in situ_ tolerance tests were also conducted with pink salmon fry, shrimp, and hermit crabs in live boxes anchored at three depths (surface, midwater, and bottom) approximately 100, 200, and 2,000 m from the drilling platform. No mortalities were recorded that could be related to the discharge plume. The authors concluded that the low toxicity of the drilling fluids, coupled with their very rapid dilution and dispersion in lower Cook Inlet, strongly suggest that discharges would result in no detectable environmental impact to pelagic organisms.

Activity: drilling.

Impact: change in turbidity or suspended sediments; change in levels of heavy metals; change in levels of hydrocarbons.

Hsiao, S.I.C. 1978. Effects of crude oils on the growth of arctic marine phytoplankton. Environ. Pollut. 17:93-108. (ADF&G, Habitat Library, #R3900.)

Hsiao determined growth responses of arctic marine phytoplankton to crude oils at various temperatures and exposures at constant light energy. Only the green flagellate Chlamydomonas pulsatilla increased survival rate with longer exposure time to the oil and also resumed normal cell division at approximately the same rate as the control. The survival rates of the three species of diatoms decreased with increasing exposure time, and they were unable to recover their normal cell division rate. In an oil-polluted environment, this could result in a phytoplankton community dominated by the green flagellate as a result of its greater survival and faster growth rates. The results of this experiment show that crude oils may either stimulate or inhibit algal growth, depending on the types and concentration of crude oil, species sensitivity, temperature, and duration of exposure.

In arctic marine waters, before the ice melts in spring, an algal bloom of mainly diatoms develops on the lower surface of sea ice and within the ice. This ice flora can constitute 24-30% of the annual productivity, and it also precedes the normal production period. This flora forms the base of the food web through zooplankton to pelagic fish. If an oil spill occurred under the ice, oil could affect this flora in three ways: 1) the oil could cause direct physical damage to the flora by coating it; 2) the presence of oil in the ice could produce a shading effect on the ice flora below and inhibit photosynthesis; 3) the more volatile components would not evaporate and could inhibit primary production. Thus, if a large oil spill changed the species composition of the phytoplankton community, zooplankton and higher trophic levels could also be affected.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Hsiao, S.I.C., D.W. Kittle, and M.G. Foy. 1978. Effects of crude oils and the oil dispersant Corexit on primary production of arctic marine phytoplankton and seaweed. Environ. Pollut. 15:209-221. (ADF&G, Habitat Library, #R0538.)

Effects of crude oil and Corexit on primary production of arctic marine phytoplankton and seaweed in the Beaufort Sea and the Eskimo Lakes in northern Canada were examined. The authors found that Corexit alone at a concentration of 10 ppm generally stimulated phytoplankton photosynthesis. The crude oil/Corexit mixtures (1:1 ratio) caused less stimulation or more inhibition of photosynthesis than did the oils alone. The authors speculated that during emulsification more of the relatively water-soluble, low-boiling, and aromatic compounds were released from the oils, thus producing a synergistic increase in the toxicity of the oils. They concluded that applying the dispersant Corexit to spilled oil results in a mixture that is far more toxic than the oil itself.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Hsieh, F.S. 1970. Storm runoff response from roadbuilding and logging on small watersheds in the Oregon Coast Range. M.S. Thesis, Oregon State University, Corvallis. 149 pp. (ADF&G, Habitat Library, #B6564.)

The effects of roadbuilding, logging, and burning upon stream runoff responses to individual storms are evaluated for the Alsea experimental watersheds, located in the Oregon Coast Range.

The results of this study indicated that roadbuilding and logging influence the hydrology of small watersheds in the Oregon Coast Range. The magnitude of influence was related to the type of land manipulation applied, the antecedent soil moisture conditions, and the percentage of drainage area treated. A portion of the major findings were as follows:

1) Roadbuilding on 12% and clear-cut logging of 72% of the same watershed increased the annual peak discharge on the average by 28 and 43%, respectively. No effect on peak discharge was observed on other study areas where percentages of roads/clear-cut were 3.1/20 and 3.7/26%, respectively.

2) Induced peak discharge increased on the severely cut areas but not the areas clear-cut to a lesser degree. Also, cutting and roadbuilding applied at headwater portions of watersheds did not noticeably affect the induced peak at the basin outlet.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water.

Hubbs, C.L., and A.B. Rechnitzer. 1952. Report on experiments designed to determine effects of underwater explosions on fish life. California Fish and Game 38(3):333. (ADF&G, Habitat Library, #R0539.)

Experiments were conducted in 1950 and 1951 in the Scripps Submarine Canyon, California, with fish in cages to determine the effects of underwater explosions. Large charges of violent explosives such as dynamite were very destructive to fish life, although repopulation of an area occurred within a few months. Charges even as small as 10, 5, 2.5 or 1.25 lb often killed fish even when the explosive had been buried many feet in the bottom sediments.

Black powder explosions proved to be relatively innocuous in a series of experiments, even with charges of 20 to 45 lb, whether the charge was buried in the sediments, resting on the bottom, or suspended near the surface. The resistence of fish to large black powder explosions is due to the relatively slow burning quality of the powder. Indications were obtained that black powder discharges do not even drive fish away or prevent them from feeding.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Huckabee, J.W., C.P. Goodyear, and R.D. Jones. 1975. Acid rock in the Great Smokies: unanticipated impact on aquatic biota of road construction in regions of sulfide mineralization. Trans. Am. Fish. Soc. 104(4):677-684. (ADF&G, Habitat Library, #R5079.)

After the completion of a highway construction project in Great Smoky Mountains National Park in 1963, a fish kill was noted in a small stream draining an area of roadbed fill. After 10 yr, the stream remained devoid of fish for at least 8 km downstream from the fill. The downstream water had a pH of 4.5 to 5.9; upstream from the fill the pH was 6.5 to 7.0. The rock material in the fill contains iron sulfide minerals. Other streams in the area flowing on the sulfide-rich rocks also showed low pH values. Survivability tests and stream surveys showed that brook trout cannot tolerate conditions in the stream below the road fill or in a stream flowing over natural outcrops of the same rock used in construciton of the road fill. Native salamanders were also adversely affected downstream from the road fill. Chemical analyses of stream water and leaching tests indicated that lowered pH and increased sulfate and metals concentrations derived from the leaching of the sulfide-rich rocks were responsible for the trout and salamander mortalities. (Authors' abstract)

Activity: grading/plowing.

Impact: change in levels of pH, alkalinity, or hardness; change in levels of other toxic compounds - sulfurous compounds; change in levels of other toxic compounds - other.

Huggins, D.G., and R.E. Moss. 1975. Fish population structure in altered and unaltered areas of a small Kansas stream. Trans. Kansas Acad. Sci. 77:18-30. (ADF&G, Habitat Library, #R5130.)

This study was designed to determine summer fish populations, species succession, species diversities and standing crop estimated in a small, slow-moving, warm-water stream that supported a population of cyprinids and other "non-sport fish" species. A section of the stream that had been previously channelized (1971) allowed investigation of the effects of channelization.

Collection of invertebrates and fish was made from channelized and unchannelized stream sections. A species list of invertebrates is presented, but no quantitative estimates were made. Numbers and weights of fish were used to calculate diversity indices and equitability measure and were extrapolated to produce section values in lb/acre. Index values indicated less species diversity in the altered section than in the unaltered sections when numbers of fish were used, but there was no significant difference in diversity when biomass units were used. The equitability component did not indicate a significant trend in sectional differences. Both biomass and numbers were less in the channelized section than in the unchannelized sections. It was concluded that the lower biomass and numbers of fish and lower diversity index values in the altered area were attributable to the effects of channelization. (Author's introduction/abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; introduction or removal of species.

Huish, M.T., and G.B. Pardue. 1978. Ecological studies of one channelized and two unchannelized wooded coastal swamp streams in North Carolina. USFWS, FWS/OBS-78/85. 72 pp. (ADF&G, Habitat Library, #B1847.)

This study on North Carolina wooded coastal swamp streams was developed to 1) describe the physical and chemical characteristics by season; 2) describe the fish species composition, movement, and abundances; 3) relate fish abundance to various stream habitats; 4) describe the use of these streams by anadromous fish; 5) describe the macroinvertebrates in the benthos and drift; and 6) describe some effects of stream channelization.

The unchannelized (natural) streams were characterized by detrital substrates, low dissolved oxygen during the summer and fall, no flow during low-water periods, wide variation in width and depth, widespread flooding during high-water periods, low water velocities, and low diurnal temperature variation. The channelized stream was characterized by high dissolved oxygen during all seasons, primarily mineral substrate, continuous flow during the year, little variation in depth or width, flooding during normal high-water periods, high diurnal temperature.

Total weights of fish per unit area were higher in the unchannelized streams than in the channelized stream due probably to lower flow rates and greater area of water. Forty-three species of fish were collected, and the relations between various stream habitats and fish species composition were described. Six species of fish present in the channelized stream were absent in the unchannelized stream. Herring, swamp fish, and flier were absent or rare in the channelized stream but common in the natural streams.

Macroinvertebrate investigations showed that physid snails and molluscs were present in the channelized stream due to high dissolved oxygen and mineral substrate but absent in the unchannelized stream. The largest average number of organisms were collected in the unchannelized streams. (Executive summary: partial)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Hunt, W.A., and R.J. Graham. 1972. Preliminary evaluation of channel changes designed to restore fish habitat. Dept. of Civil Eng. and Eng. Mechanics, Montana State Univ., Bozeman. 42 pp. (ADF&G, Habitat Library, #B1829.)

An evaluation of the fish habitat in two meanders constructed in the Clark Fork River west of Drummond, Montana, shows the hydraulic, topographic, and fish population characteristics of these artificial meanders to be similar to those found in comparable natural sections of the river. A design procedure based on observations of the meanders in the stream being altered is recommended. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water.

Hurley, D.A., and W.L. Woodall. 1968. Responses of young pink salmon to vertical temperature and salinity gradients. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 19. New Westminister, B.C. Canada. 80 pp. (ADF&G, Habitat Library, #B6179.)

This report does not pertain to a specific developmental activity. However, it is included here because it offers specific information on the environmental requirements of young pink salmon and is useful for evaluating other studies that involve changes in similar environmental variables as a result of developmental activities.

Evidence that the large variations in Fraser River pink salmon (Oncorhynchus gorbuscha) runs may be determined by mortality rates during early marine residence prompted investigation into the response of pink salmon fry to certain environmental conditions characteristic of the estuarial region. Experimental stocks of pink salmon were held for as much as 3 mo after emergence and tested at regular intervals in separate vertical gradients of temperature and salinity. Stocks of fry held in fresh water died within 5 wk or less, but others were held without mortality in increasing salinities and also tolerated immediate transfer into 30 to 31 ppt (o/oo) sea water within 1 d of emergence. The diet of marine plankton provided a slightly slower rate of growth than estimated for wild fry, but the condition of experimental fish compared favorably with wild pink salmon.

When tested in a vertical gradient, fry up to 3 mo of age selected a restricted range of temperatures which decreased as fish increased in size. The youngest fry generally selected temperatures between 53 and 56°F; older fry were found in temperatures from 49 to 51°F. Increasing salinities were selected in an orderly sequence as fry made the transition from fresh water to sea water. Transition to salinities of 30 to 31 ppt o/oo required less than one month for all stocks tested but varied with the time of emergence. Tests of early, peak, and late segments of an emergence curve indicated progressively more rapid movement into sea water by the later emerging fry. The experimental findings are examined in relation to the behavior of pink salmon fry observed in nature, and implications for survival are discussed. (Author's abstract: modified)

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in level of salinity.

Irizarry, R.A. 1969. The effects of stream alteratnion in Idaho. Idaho Department of Fish and Game. Federal aid in fish and wildlife restoration, job completion rept. Proj. F-55-R-2. 26 pp. (ADF&G, Habitat Library, #B1851.)

Investigations were conducted to evaluate the number of stream miles subjected to artificial alteration and compare the standing crop of game fish between equal areas of altered and unaltered stream sections.

In the physical inventory phase of this project, 1,138 mi of stream were studied during a 2-yr period. The number of altered stream miles were calculated at being approximatley 434 mi, which, converted to percentage, revealed that an average of 38% alteration had occurred within the 45 study streams. This was an occurrence of 1-1/4 alterations per stream mile, with the average length of a channel alteration being 1,935 ft.

Encoachment of road materials was responsible for 55% of the alterations, 20% was due to channel relocation, 13% to mining, 11% to channel clearance, and 1% to riprapping. Sixty percent of the alterations were associated with road-building activities, 19% with flood-control projects, 13% with mining, 6% with railroad construction, and 2% with agriculture and other miscellaneous activities.

Biological sampling in 29 different streams found that there were almost 7 times as many catchable-sized trout and almost 10 times as many catchable-sized whitefish censused in unaltered (natural) stream sections as in altered stream sections. The undisturbed areas out-produced the altered areas, ranging from 1.4 to 112 times greater in poundage of game fish. In some instances, the altered areas produced no game fish whatever.

Average fish production, in poundage, was eight times greater in undisturbed stream sections; in numbers of game fish, the natural areas out-produced the altered areas six to one.

Activity: channelizing waterways; grading/plowing; processing minerals.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments.

Jehl, J.R., M.J. White, and S.I. Bond. 1980. Effects of sound and shock waves on marine vertebrates: an annotated bibliography. USDI: USFWS. Washington, DC. (ADF&G, Habitat Library, #B6256.)

This annotated bibliography lists 25 studies and reports on the interactive effects of underwater acoustic signals and explosions on various forms of marine life. Also listed are studies on the use of sound as an attractant or deterrent. This bibliography includes United States and foreign research conducted from 1977 to 1978 and covers the literature on the interaction between underwater acoustic signals and fish, birds, and mammals.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise; artificial attractant to biological organisms.

Jenkins, S.H. 1978. Effects of domestic sewage on marine phytoplankton. Mar. Pollut. Bull. 9(6):3568. (ADF&G, Habitat Library, #R3658.)

In order to assess the importance of domestic sewage as a factor in the development of phytoplankton, selected marine species were grown experimentally in sterile seawater containing mineral nutrients and various concentrations of sewage. The results show that the biomass was affected both qualitatively and quantitatively by the concentration of nitrate nitrogen and phosphate. In excess of 0.1 mg N/l as nitrate and 0.017 mg P/l orthophosphate the number of algal cells increased to about 1 million/l. This concentration was considered as diagnostic on conditions favoring eutrophication. The author briefly discusses the impact of domestic sewage discharged from the River Danube on the Black Sea.

Activity: sewage disposal.

Impact: change in levels of nutrients.

Jensen, J.O.T., and D.F. Alderdice. 1983. Changes in mechanical shock sensitivity of coho salmon (Oncorhynchus kisutch) eggs during incubation. Aquaculture 32:303-312. (ADF&G, Habitat Library, #R3597.)

A device is described for determining the sensitivity of salmonid eggs to mechanical shock. Eggs were dropped under controlled conditions, and sensitivity was determined as the median shock limit - the drop height (cm) or work expended (ergs) resulting in 50% mortality among tested samples. Groups of incubating (10°C) coho salmon (Oncorhynchus kistuch) eggs were exposed to a series of standardized shock intensities at 29 intervals from fertilization and activation (addition of water to mixed gametes) until hatching. Median shock limit estimates defined three levels of increasing shock sensitivity (ergs/egg): level 1, occurring between 10 and 45 min (12.8×10^3); level 2, between 2 and 72 h (4.8×10^3); and level 3, between 4 and 14 d (1.6×10^3) after activation. The first level of sensitivity occurred prior to first- cell division. The second level spanned the cell cleavage phase and the third level, the gastrulation phase. Thereafter, sensitivity began to decline, beginning with completion of epiboly (day 14), until the early eyed stage was reached (day 20) when it no longer was detectable. Based on the results some recommendations are given regarding egg manipulation, chemotherapeutic treatment, and transportation of gametes or fertilized eggs. (Author's abstract)

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Johansson, S, U. Larsson, and P. Boehm. 1980. The Tsesis oil spill: impact on the pelagic ecosystem. Mar. Pollut. Bull. 11:284-293. (ADF&G, Habitat Library, #R3570.)

On 26 October, 1977, the tanker Tsesis grounded in the Swedish archipelago, 65 km south of Stockholm. The Tsesis carried 17,575 metric tons of No. 5 fuel oil. The total spill was estimated as being somewhat more than 1,000 metric tons, of which about 600-700 metric tons were recovered, thus leaving about 300 metric tons in the environment. The effects on the pelagic ecosystem were studied for 1 mo following the spill. Severe effects were recorded only in the immediate vicinity of the wreck, where zooplankton biomass declined substantially during the first few days after the spill. Within 5 d the zooplankton biomass was reestablished. Oil contamination of zooplankton was recorded for over 3 wk. It is suggested that an increased phytoplankton biomass and primary production in the impacted area were due to decreased zooplankton grazing rates. Increased bacterial numbers and the pil degradation pattern indicated a rapid bacterial degradation of hydrocarbons in the water column.

Sediment traps positioned in the area demonstrated the importance of sedimentation as a pathway for removal of oil from the water column. During the second week after the spill, 0.7% of the sedimented material was petroleum hydrocarbons. Using sediment trap data, a total sedimentation of 30-60 metric tons of oil was estimated in the impacted area (42 km^2). This corresponds to 10-15% of the unrecovered oil.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Johnson, C. 1984a. Effects of coastal development for oil and gas on anadromous fisheries in the Beaufort Sea. Presentation to Beaufort Sea Annual Review. Anchorage, AK. May 23,1984. (ADF&G, Habitat Library, #R2412.)

Causeways that extend into the brackish nearshore zone are identified as a major coastal development activity in the Alaskan Beaufort Sea region. The primary environmental concern arising from causeway construction is the effect such a structure would have on fish migrations. A number of studies are underway to investigate causeway impacts in the Beaufort coastal area. Preliminary evidence indicates that causeways do not physically impede fish movement but that sharp temperature/salinity gradients created by the structures do impede fish movement. In the Beaufort region, anadromous fish that are delayed in reaching their overwintering habitat could face high overwintering mortality.

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; addition of physical barriers - partial obstructions; change in level of salinity.

Johnson, R.A. 1984b. Gold placer mining in Alaska and sediment discharge. The Northern Engineer 16(2):4-10. (ADF&G, Habitat Library, #R3292.)

This literature review covers several areas where the effects of placer mining are felt. The author states that information specific to placer mining in Alaska is lacking and little research is being supported. Sound evidence exists that total suspended solid concentrations below 25 mg/l have no direct harmful effects on fisheries (e.g., gill abrasions, feeding impairment etc.), whereas 100-400 mg/l is unlikely to support good fisheries. [See Lloyd (1985) for review of indirect effects of suspended solids at concentrations below 25 mg/l.] The author cites works that found a strong basis for concluding that placer gold mining can affect fish reproduction, growth, and survival. Further, streams subjected to unnatural silt loads may require from 5 to over 20 yr to recover. A study being conducted within the Birch Creek drainage (Interior Alaska) has shown that algal productivity and invertebrate density and diversity are all depressed and that caged fish had reduced fat tissue as a consequence of placer mining on that stream.

The author concludes that untreated placer mining effluent waters can introduce substantial amounts of particulates into receiving waters. Properly designed and operated settling ponds can efficiently remove settleable solids. However, because of clay and silt, turbidity removal is much more difficult. Alaska water quality standards on turbidity are virtually impossible to attain with settling ponds alone.

Activity: dredging; processing minerals.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Johnson, J.H., R.C. Solomon, C.R. Bingham, B.K. Colbert, and W.P. Enge. 1974. Environmental analysis and assessment of the Mississippi River 9-ft channel project between St. Louis, Missouri, and Cairo, Illinois. Tech. Rept. Y-74-1. U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi. 143 pp. (ADF&G, Habitat Library, #B1719.)

In the middle Mississippi River, 122 mi of revetments stabilize the riverbanks by preventing or greatly reducing erosion. By this method, bend migration has been reduced to the extent that the river is no longer free to migrate and to produce new side channels. The loss of potential new natural channels is offset by the formation of human-made channels constructed during river development and modification. Some of the effects of revetments on river morphology and behavior are similar to those dikes, since both revetments and dikes serve cumulatively to contract the river. Colorado State University workers, as part of this study, have shown that contraction of the river has generally caused the reduction of river surface area, island area, riverbend area, river width, and corresponding bank-full channel and cross-sectional areas. Because revetments have kept the river channel narrow, riverbed degradation has occurred with a subsequent lowering of the riverbed elevation. As a consequence of areal reductions, the potential habitat available for aquatic organisms has been reduced. However, preliminary field observations by the Waterways Experiment Station (Corps of Engineers, USA) personnel indicate that rock revetment may create a superior habitat by providing great diversity for aquatic organisms through stabilization of the river banks. Ecology of the revetments needs further study. (Annotation from Stearn and Stearn 1980b)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Johnston, D.W., and D.J. Wildish. 1981. Avoidance of dredge spoil by herring (Clupea harengus harengus). Bull. Environ. Contam. Toxicol. 26:307314. (ADF&G, Habitat Library, #R3897.)

The purpose of these laboratory experiments was to determine the avoidance threshold of juvenile Atlantic herring to a representative sample of sediment to be dredged and dumped in a New Brunswick estuary. The herring exposed to the suspended sediment showed an avoidance threshold between 9 and 12 mg/l. Decreased light caused partial inhibition of the avoidance behavior. Conditioning experiments indicate that juvenile herring can learn to avoid suspended sediments.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

Johnston, C.E., R.L. Saunders, E.B. Henderson, P.R. Harmon, and K. Davidson. 1984. Chronic effects of low pH on some physiological aspects of smoltification in Atlantic salmon (Salmo salar). Can. Tech. Rept. Aquat. Sci. 1294: 7 pp. (ADF&G, Habitat Library, #B1788.)

Atlantic salmon (Salmo salar) were chronically exposed for several months to acidified water to determine if mean pH levels of 4.7 and 4.9 prevent smoltification from proceeding normally. Physiological changes associated with smoltification developed normally when pH was above 4.9. When pH fell below 4.7, there was impairment of ionic regulatory mechanisms, leading to excessive loss of electrolytes in fresh water. Failure oionic regulation appeared to follow an inhibition of Mg^{+}+)-ATPase and (Na^{+}, K^{+})-ATPase enzyme systems. Prolonged exposure to acid water allowed salmon to develop compensatory branchial mechanisms, including increased ATPase activity, that led to improved ionic regulation. (Author's abstract)

Activity: processing minerals.

Impact: change in levels of pH, alkalinity, or hardness.

Kaas, R. 1981. Evolution des peuplements algaux exploitables depuis le naufrage de l'Amoco Cadiz. In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4337.)

Since January 1979, the algology department of ISTPM followed the hydrocarbon effects on one of the most commonly used seaweeds of the French coast, Laminaria digitata. Density observations were also made on a red algae, Chondrus crispus. In general, the density of laminaria did not change. The same was true for amounts of alginic acid. On the other hand, growth was more important at polluted stations than at reference stations. Similarly, heterogeneity of thallus dimensions was greater at the polluted stations. Current reproduction is similar to previous years. The decrease of Chondrus crispus biomass is the most important finding. Biomass was two to three times lower than in previous years.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Karinen, J.F. 1980. Petroleum in the deep sea environment: potential for damage to biota. Environ. Int. 3:135-144. (ADF&G, Habitat Library, #R3682.)

Information on the fate, persistence, and biological impact of petroleum hydrocarbons in shallow marine environments, coupled with recent data on hydrocarbons in offshore sediments and the biology of deep-sea organisms, have provided new perspectives on the potential impact of oil on the deep-sea environment. A review of literature on petroleum hydrocarbons in deep-sea sediments, mechanisms for transport of petroleum to the deep-sea floor, interaction of petroleum hydrocarbons and particulate matter, and the physiology and metabolism of deep-sea fish and crustaceans has resulted in the following conclusions:

1. Hydrocarbons of apparent anthropogenic origin are accumulating in bottom sediments of coastal margins and in deeper offshore waters at unknown rates.

2. Several mechanisms exist for the rapid transport of petroleum hydrocarbons to the deep-sea floor.

3. Petroleum hydrocarbons are intimately associated with particulate matter in the sea and behave much the same as natural biogenic material and have the potential to modify or interrupt natural processes.

4. The unique physiology of deep-water life forms increases the potential for adverse impact of petroleum hydrocarbons in the deep-sea environment.

5. There is a need to determine trends of temporal and spatial deposition of hydrocarbons in deep-sea sediments and evaluate the biological impact of this introduction of xenobiotic compounds on the largest environment on earth. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Karna, D.W. 1978. Investigations of seven disposal locations used by seafood processors at Dutch Harbor, Alaska. October 1976, September 1977. EPA Surveillance and Analysis Division. Seattle, Washington. Working Paper No. EPA 910-8-78-101. 48 pp. (ADF&G, Habitat Library, #B6246.)

Dutch Harbor disposal locations were observed by scuba divers in 1976 and 1977. On the west side of Amaknak Island, definite accumulations of both old and newly deposited wastes were observed. Some wastes were dispersed by water movements, and some, especially the visceral organs and tissues that are partially suspended in the water column, are fed on by aquatic organisms. Reduction of waste by these processes, however, is not as great as the rate of waste accumulation, as increasingly large sludge beds develop.

On the northeast side of Iliuliuk harbor, the divers in 1977 observed only shallow remnant deposits of the ground shellfish wastes that were discharged in 1976. Several factors probably contributed to the reduction of waste: 1) less was discharged here than on the west side of the island, 2) the discharge line was moveable, so wastes were spread in shallow deposits over a large area, 3) wastes were discharged in shallow (4 to 8 m) water, so the waste may have been more exposed to tidal action, and 4) a greater concentration of crab, shrimp, and fish were observed than on the west side of the island.

Concentrations of hydrogen sulfide in sludge and water samples from both old and new disposal areas ranged from 0.1 to 5.9 mg/l. Shellfish waste beds smothered all immobile organisms in the area. At several locations, dead, dying, and apparently stressed clams were observed under a layer of waste only 1-2 cm deep. Benthic communities on the natural substrate in the areas adjacent to the disposal locations had significantly fewer organisms than were present in the control area on the same side of the island.

Activity: solid waste disposal.

Impact: addition of substrate materials; change in levels of other toxic compounds - sulfurous compounds.

Karr, J.R., and I.J. Schlosser. 1977. Impact of nearstream vegetation and streams morphology on water quality and stream biota. U.S. Environmental Protection Agency. EPA-600/ 3-77-097. 91 pp. (ADF&G, Habitat Library, #B1819.)

Like all functional parts of landscape units, streams have dynamic equilibria in nutrient and sediment loads and biota. As man modifies watersheds by removal of natural vegetation and stream channelization, disequilibria in both the terrestrial and aquatic environments result. These disequilibria are the major problem in controlling sediments and nutrients from nonpoint sources and improving the quality of the stream biota. Unfortunately, most attempts to control nonpoint pollutants in agricultural watersheds emphasize reestablishing the terrestrial equilibrium via tillage practices such as minimum tillage, winter crop cover, and terraces. These efforts, which depend on erosion control as measured by the Universal Soil Loss Equation, utilize technologies for preserving soil productivity. This approach must be replaced by one in which improvement in water quality and quality of the stream biota is a primary objective. This requires erosion control on the general landscape plus an increased understadning of the link between terrestrial and aquatic systems and the effect of stream morphology on the dynamics of sediment transport and quality of the stream biota.

In this report, we review the literature dealing with 1) the possible use of near-stream vegetation to reduce the transport of sediment and nutrients from the terrestrial to the aquatic environment and decrease stream temperature fluctuations, 2) the effect of stream morphology on sediment transport, and 3) how near-stream vegetation and stream morphology affect the biota of streams. The results of this review suggest that proper management of near-stream vegetation and channel morphology can lead to significant improvements in both the water and biological quality of many streams. However, critical research outlined in this report is still necessary if we are to properly use this management alternative to attain the objectives of the Federal Water Pollution Control Act of 1972 (Public Law 92-500).

This report was submitted in fulfillment of Contract No. 68-01-3584 by the University of Illinois, Champaign, IL, under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from January 1976 to July 1977, and work was completed as of July 1977. (Author's abstract)

Activity: channelizing waterways; clearing and tree harvest; grading/plowing; processing minerals.

Impact: change in water temperature; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; change in levels of nutrients.

Kathman, R.D., S.F. Cross, and M. Waldichuk. 1984. Effects of wood waste on the recruitment potential of marine benthic communities. Can. Tech. Rep. Fish. Aquat. Sci. 1284: 50 p. (ADF&G, Habitat Library, #B1079.)

Replicate samplers containing varying concentrations of wood wastes and sediments were deployed in 25 m of water in outer Burrard Inlet on 1 August 1983 for benthic invertebrate colonization. After 11 weeks, on 20 October 1983, the samplers were retrieved and the benthic macroinvertebrates were identified and enumerated. Data analyses included dominance and diversity measures, hierarchical (cluster) classification and ordination techniques. Species richness, diversity, and evenness values were highest and dominance values were lowest in the 20% wood waste samples, compared to the 0, 50, and 100% wood waste concentrations. The sample cluster analysis clearly differentiated two groups: one containing almost all of the 0 and 20% samples and the other containing almost all of the 50% and all ofthe 100% samples. Species cluster analysis indicated three distinct groups of taxa. The first group, comprised of polychaetes and oligochaetes, and the second group, containing polychaetes and bivalves, are both indicative of low concentrations of wood fibres. The third group contained nematodes, the wood-burrowing shipworm Bankia setacea, and the polychaetes Armandia brevis, Capitella capitata and Prionospio cirrifera, all typically associated with high levels of organic enrichment (pollution). The similar patterns among all data analyses confirmed the greater recruitment potential of marine macroinvertebrates in sediments containing some wood wastes. Enhancement occurred between 10 and 40% wood content, while higher wood content was detrimental to marine organisms. (Author's summary)

Activity: log storage/transport; processing lumber/kraft/pulp.

Impact: addition of substrate materials.

Keefer, L.C. 1977. The effects of headwater reservoirs and channelization on invertebrate drift in Piedmont streams. M.S. Thesis, Virginia Polytechnic Inst., State Univ. Virginia, Blacksburg, VA. 121 pp. (ADF&G, Habitat Library, #B1986.)

Channelized streams tended to have higher drift densities and lower benthic standing crop densities than unchannelized streams. Drift densities increased markedly below a small flood control impoundment as a result of the influx of large numbers of organisms of limnetic origin. The density of these organisms in the drift decreased rapidly as the distance downstream from the reservoir increased. (Author's abstract)

Activity: channelizing waterways; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water.

Keller, E.A., and F.J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes 4:361-380. (ADF&G, Habitat Library, #R5128.)

Stream channel development in forested areas is profoundly influenced by large organic debris (logs, limbs, and rootwads greater than 10 cm in diameter) in the channels.

In low-gradient meandering streams, large organic debris enters the channel through bank erosion, mass wasting, blowdown, and collapse of trees due to ice loading. In small streams, large organic debris may locally influence channel morphology and sediment transport processes because the stream may not have the competency to redistribute the debris. In larger streams, flowing water may move large organic debris, concentrating it into distinct accumulations (debris jams). Organic debris may greatly affect channel form and process by increasing or decreasing the stability of stream banks; influencing development of mid-channel bars and short braided reaches; and facilitating, with other favorable circumstances, development of meander cutoffs.

In steep-gradient mountain streams, organic debris may enter the channel by all the processes mentioned for low-gradient streams. In addition, considerable debris may also enter the channel by way of debris avalanches or debris torrents. In small-to-intermediate-size mountain streams with steep valley walls and little or no floodplain or flat valley floor, the effects of large organic debris on the fluvial processes and channel form may be very significant. Debris jams may locally accelerate or retard channel bed and bank erosion and/or deposition; create sites for significant sediment storage; and produce a stepped channel profile, herein referred to as 'organic stepping', which provides for variable channel morphology and flow conditions.

The effect of live or dead trees anchored by rootwads into the stream bank may not only greatly retard bank erosion but also influence channel width and the development of small scour holes along the channel beneath tree roots. Once trees fall into the stream, their influence on the channel form and process may be quite different from when they were defending the banks, and, depending on the size of the debris, size of the stream, and many other factors, their effects range from insignificant to very important. (Author's abstract)

Activity: channelizing waterways; clearing and tree harvest; grading/plowing.

Impact: alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Kelly, J.P. 1975. Stream channelization and fish diversity in the Luxapalila River in Alabama and Mississippi. Ph.D. Dissert., Dept. of Zoology, Mississippi State Univ. 104 pp. (ADF&G, Habitat Library, #B2794.)

Three segments (recently channelized, unchannelized, and older channelized) of the Luxapalila River in northeast Mississippi and northwest Alabana were studied from July 1973 to December 1974 to determine if differences existed in fish species diversity between the channelized and unchannelized segments. Day and night fish collections were made monthly by seining. All fishes were categorized as resident or transient based on the frequency of their occurrence (> 10% = resident). Habitat associations were reported for all resident species.

Physicochemical parameters were not different (P<.05) among stations except for surface flow rate, which was much slower in the recently channelized area, and turbidity, which was lowest in the older channelized section. Although reduced current in the recently channelized seciton was a limiting factor, other physicochemical factors were not significant in determining species diversity.

Eighty-two species of fishes were collected, with 62 in the recently channelized section, 67 in the unchannelized section, and 45 in the older channelized section. Nearly half (46%) of the species occurring in the recently channelized section were transient species, whereas 22.4 and 24% were transients in the unchannelized and older channelized segments, respectively.

The Whilm and Dorris diversity index and the Jaccard similarity coefficient showed the unchannelized segment of the river to be the most diverse, and the recently channelized segment was the least diverse. Sixteen species were collected in the unchannelized section that were not taken in the recently channelized area, and nine species occurred only in the recently channelized area. Total abundance was generally high for the recently channelized area, but 32 species were lower in frequency of occurrence in this segment.

Discriminant analysis proved to be a useful tool to separate the three areas based on the habitat associations of the respective faunas. Bottom fishes were the most severely reduced forms in the recently channelized area, whereas open-water forms were greatly reduced at the older channelized section. Siltation, simplification of bottom type, and reduction of current appear to be the limiting factors at the recently channelized area, whereas lack of quiet habitat, unstability of the bottom, and lack of deep-water habitat appear to be the limiting factors at the older channelized area.

Future modification of the river may eliminate Armmocrypta asprella and Noturus munitus from this area and also cause severe reductions in abundance of 14 other species.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

Kineman, J.J., R. Elmgren, and S. Hansson (eds). 1980. The Thesis [i.e. Tsesis] oil spill: report of the first year scientific study (October 26, 1977 to December 1978): a cooperative international investigation. NOAA. (ADF&G, Habitat Library, #B2672.)

The Tsesis oil spill on Oct. 26, 1977, released about 1,100 tons of oil, mostly a No. 5 fuel oil, but also some bunker oil. A cooperative international scientific investigation studied the ecological effects on plankton, benthos, fish, littoral and supralittoral communities, as well as the chemical and biochemical processes of weathering, bioaccumulation and depuration. The site had been relatively well studied in the past during several marine biological programs.

The direct effects on the plankton included decreased zooplankton biomasses in the immediate vicinity of the tanker. Within days, increased phytoplankton biomass and primary production, as well as bacterial abundance, were noted in a larger area surrounding the tanker. Here, zooplankton abundance and biomass were apparently not affected , in spite of considerable contamination of zooplankton by oil droplets. No contamination or harmful effects on pelagic fish could be demonstrated. In a small bay near the spill site, oil concentrations of 60 ug/l were found in the water below a weathered oil slick. After 1 mo, all parameters measured in the pelagic zone had returned to normal values.

Damage to bird life and the littoral zone was alleviated by the season of the spill, which was characterized by low standing stocks and production of plants and animals. The supralittoral zone showed little damage when surveyed the following summer. In the littoral zone, no effects on the algae were seen, but the fauna of the most heavily oiled coastline showed direct effects. Crustaceans were especially hard hit, but less than a year later, recovery was well underway. Oil analyses of mussels, Mytilus edulis, showed that oil had reached a larger area than was visibly impacted. Extremely high oil levels were found in Mytilus after the spill, and a year later, Tsesis oil was still evidenced in the mussels.

Sediment traps deployed in the area collected material strongly contaminated with oil for the first weeks after the spill, demonstrating that oil was rapidly transported to the benthos. A minimum sedimentation of about 20 tons of oil was estimated. About 2 wk after the spill, when the first samples were taken on deeper (30 m) soft bottoms, oil impact was already extensive. At the most heavily affected station, motile macrofauna were greatly reduced, possibly through emigration. The sedentary species remained, and no increase in their mortality was demonstrated. Macoma balthica showed high oil levels over a large area, even at stations where no clear impact was shown by macrofauna community composition. All meiofauna groups, except the nematodes, were also reduced at the affected station, and there was evidence of high mortality of ostracods. A few months after the spill, the few remaining gravid amphipod (Pontoporeia affinis) females at the most affected station showed an increased frequency of abnormal eggs. The recovery of the deep soft bottoms after oil damage proved slower than for other systems studied. About 10 mo after the spill, neither macro- nor meiofauna at this station showed any recovery, and oil levels in Macoma balthica were higher than immediately after the spill.

In June, 7 mo after the spill, the herring showed less spawning and lower hatching success in the oiled area than in a reference area. This might be due to factors other than oil and needs confirmation.

The chemical analysis by Gas Chromatography (GC) and Mass Spectrometry (MS) showed rapid weathering of the Tsesis oil, and all oil found in biota in sediment trap material was altered in composition but identifiable as Tsesis oil. Depuration in Mytilus and Macoma showed more rapid elimination of the aliphatic than the aromatic fractions. The trimethylbenzenes were identified as a fraction particularly resistant to degredation. The oil analyses proved invaluable for correct interpretation of the ecological data.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

King, D.L., and R.C. Ball. 1964. The influence of highway construction on a stream. Michigan State Univ. Agri. Exp. Sta., East Lansing, Research Rept. No. 19. 4 pp. (ADF&G, Habitat Library, #R2720.)

This paper discusses impacts of a limited-access interstate highway on the Red Cedar River, which drains a watershed of 355 mi^2. The highway parallels the river and crosses several major tributaries at points ranging from 2 to 5 mi from the main river. A relatively large amount of bare ground necessary for construction coupled with heavy rains caused an increase in the amount of inorganic sediments entering the river. No quantitative information is offered to compare before and after effects. The author states that the highest measurement of turbidity (387) occurred during the heavy rains; however, no unit of turbidity measure is cited.

Three direct effects on the river are cited: 1) turbidity reduced light penetration, thereby decreasing the amount of energy available for photosynthesis; 2) the concentration of inorganic material in the river scoured organisms from the stream bed; and 3) inorganic sediment settling on the bottom suffocated many of the remaining organisms.

The impact of sediments upon macroinvertebrate populations includes the reduction in numbers and biomass of herbivorous insects and tubificid worms.

No quantitative information is presented concerning fisheries impacts. The author discusses the probable reduction in fish populations due to a reduction in suitable habitat. The species discussed (smallmouth bass) has no relevance to Alaska. However, fisheries habitat most impacted were deep pools. Many previously deep pools in the vicinity of road construction were filled in, and this destruction of habitat would have similar impacts to Alaskan fish species that spend a portion of their life cycle in pools.

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

King, L.R., and K.D. Carlander. 1976. A study of the effects of stream channelization and bank stabilization on warmwater sport fish in Iowa: Subproject No. 3. Some effects of short-reach channelization on fishes and fish food organisms in central Iowa warm water streams. Iowa Cooperative Fishery Research Unit, Iowa State University. USFWS, Office of Biological Services FWS/obd-76-13. (ADF&G, Habitat Library, #B0992.)

Six central Iowa streams were studies in 1974 to determine whether fish and fish food organisms were affected by short-reach channelization associated with bridge replacement during the last 15 yr. More fish species were collected by electroshocking in unchannelized than in channelized areas in five of the six streams and in the sixth, the number of species was the same in both areas. In two recently channelized streams that lacked cover in the channel, catches of fish were significantly less in the channelized than in the unchannelized areas, but in three streams channelized 10 to 15 yr where some cover had developed, catches in the channel runs were similar or significantly greater than in the unchannelized runs. In the unchannelized area, however, more of the fish were in brush and total populations were not adequately sampled by electroshcoking. The most evident impact of short-reach channelization is the removal of cover in the altered area and the loss of stream length. (Author's abstract: modified)

Activity: channelizing waterways.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

Klaverkamp, J.F., W.L. Lockhart, D. Metner, and N. Grift. 1976. Effects of chronic DDT/DDE exposure on anesthetic induction and recovery times in rainbow trout (Salmo gairdneri). J. Fish. Res. Bd. Can. 33: 1331-1334. (ADF&G, Habitat Library, #R3959.)

In rainbow trout (Salmo gairdneri) fed pellets containing 4.55 ug/g of 1,1,1,-trichloro-2,2-bis[p-chlorophenyl]ehtane (p,p'-DDT) and 6.81 ug/g of p,p'-DDE every other day, anesthetic induction and recovery times of phenoxyethanol (PE) were less than those in trout fed control pellets. Chronic feeding of DDT and DDE significantly reduced the time required for complete anesthesia with PE but did not have any effect on M.S. 222 anesthetic times.

No interactions were observed in fish fed DDT/DDE and anesthetized with ethyl m-aminobenzoate methanesulphonate (M.S. 222). Differences observed between fish fed DDT/DDE and anesthetized with PE as compared to M.S. 222 could be due either to enhanced metabolism of PE or to the fact that PE and M.S. 222 have different modes or sites of action. (Author's abstract: modified)

Activity: chemical application; sewage disposal.

Impact: change in levels of other toxic compounds - other.

Kochenderfer, J.N. 1970. Erosion control on logging roads in the Appalachians. USDA: Forest Service Res. Pap. NE-158. 28 pp. (ADF&G, Habitat Library, #B1828.)

This extensive review paper covers many aspects of logging road construction and maintenance of logging roads and is a very good source of basic information. In most respects, erosion on forest roads is like erosion on farmland. The basic problem in both places is the swift flow of storm water over bare, steep ground from which the protective plant cover has been removed. Although for many years timber harvesting has been associated with deterioration of forest land and streams, the mere cutting of trees is not the cause of erosion damage. In logging operations, roads are the primary area where soil is dangerously exposed. The soil compaction and loss of protective and absorbent litter prevent rain from soaking into the soil surface as rapidly as it falls. This causes water to collect on the road surface and run over exposed soils.

Careful planning can eliminate undesirable building practices that result in washed-out roads and silted streams. A minimum amount of land dedicated to road surface makes for more efficient logging and is also one of the best ways to reduce erosion on logged areas. Roads in steep terrain should be planned so tree-length logs can be yarded uphill to them. This reduces disturbances because the ends of logs pulled uphill do not readily gouge the forest floor. Although the best rule is to locate roads and landings as far from streams as possible, when this is not practical, logs should be yarded away from streams, rather than across or down stream channels. The best logging roads should be planned for areas of greatest use. Sections of road near the ends of road systems and in other areas of light use do not have to be as well constructed as main roads that receive heavy use.

Although a minimum grade of 3% is desirable to provide adequate drainage, foresters generally agree that logging roads should seldom exceed 10%. Roads laid out on a 10% grade often end up varying between 5 and 15% after construction. Constructed roads also vary from proposed locations because they are often built around obstacles like large trees and rocks that could not be avoided during layout.

Buffer strips between logging roads and streams usually prevents muddy road water from reaching streams. The width of buffer strips varies with the steepness of slope between road and stream. A minimum distance of 100 ft is recommended between logging roads or landings and streams.

Several drainage devices have been developed for controlling water flow on logging roads. Culverts are probably most common. Erosion can be prevented at culvert outlets by installing rocks for the culvert outflow to spill on. Outsloping of roads and broad-based dips can also be used for road drainage.

Suitable stream-crossing sites are a prime consideration when locating logging roads. A narrow place with relatively low banks and firm, rocky soil usually makes the best crossing. Bridges or fords should be used to cross streams too large to carry in culverts. Fords can be used where clean water is not a primary consideration and a firm rock base can be established. All crossing sites should be at right angles to the stream and should not interfere with natural streamflow. Roads should climb away from stream crossings in both directions to prevent high water from running down roads.

Methods of proper road maintenance, traffic regulation, and care after logging are discussed.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Kopperman, H.L., D.W. Kuehl, and G.E. Glass. 1975. Chlorinated compounds found in waste treatment effluents and their capacity to bioaccumulate. Cahpter 16 in R.L. Jolley, ed Water chlorination, environmental impact and health effects. Vol. 1. Proceedings of the conference on the environmental impact of water chlorination, Oak Ridge, TM. Oct. 22-24, 1975, Ann Arbor, Michigan. Ann Arbor Science Publishers. (ADF&G, Habitat Library, #R3974.)

As part of an ongoing research program to assess possible long-term environmental effects due to the formation of stable reaction products during disinfection processes, fish (fathead minnows, *Pimephales promelas*) and water from the 9-mo chronic toxicity tests at two wastewater treatment plants in Michigan are being analyzed for chemical residues at this laboratory (formerly named the National Water Quality Laboratory).

Gel permeation chromatography was used for sample cleanup, and gas chromatography/mass spectrometry was used for sample analysis. Di- and trichlorophenols, di- and trichlorobenzenes and trichloroanisoles were not detected at lower levels in the fish from nondisinfected effluent exposures compared to fish exposed to chlorinated effluent. Tetra- and pentachlorophenols, PCBs, DDTs, toxaphene components, chlordane, and nonachlor were found in all fish raised in the sewage effluent. Tribromoanisole was tentatively identified in fish that lived in BrCl-treated wastewater.

Reports appear to be conclusive in support of the argument that even the most gentle chlorination conditions will cause chlorine to be incorporated into organic molecules. The incorporation of chlorine into an organic molecule increases its lipophilic character and at the same time normally causes an increase in the observed toxicity or bioaccumulation or both.

The persistence of these compounds is now becoming a concern. Not all organochlorine compounds bioaccumulate to high levels. The data suggest that polar compounds are more easily biodegraded and that nonpolar (highly lipophilic) compounds accumulate. Some investigators have been able to demonstrate positive correlation between the n-octanol/water partition coefficients for given compounds and their ability to bioaccumulate in various species of fish. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Korn, S., and S. Rice. 1981. Sensitivity to, and accumulation and depuration of, aromatic petroleum components by early life stages of coho salmon (Oncorhynchus kisutch). Rapp. P.-v. Reun. Cons. Int. Explor. Mer 178:87-92. (ADF&G, Habitat Library, #R3686.)

Coho salmon eggs, alevins, and fry were exposed to toluene, naphthalene, and 1-methylnaphthalene (aromatic hydrocarbons found in crude oil) in a series of short-term toxicity and hydrocarbon-uptake studies to determine whether acute toxicity is related to uptake-depuration patterns. Uptake studies used radio-labeled compounds and radiometric analyses. The time to reach maximum tissue concentrations of these hydrocarbons was determined from long-term exposures.

Sensitivity to the aromatic hydrocarbons increased from egg to fry with the greatest increase in sensitivity between th egg and early alevin. The rates of uptake and depuration of the aromatic hydrocarbons also increased during the development from egg to fry. Eggs had the slowest rates of uptake and depuration.

Eggs required 10 d to accumulate stable tissue concentrations of toluene and naphthalene; alevins required 36 h (both toxicants); fry required 3 h (toluene) and 10 h (naphthalene). The rate of uptake and toxicity was higher with increased substitution (i.e., 2-methylnaphthalene greater than naphthalene greater than toluene).

Eggs were more tolerant than alevins and fry to short-term exposures of aromatic hydrocarbons probably because the chorion prevented rapid uptake. The amount of yolk also influenced sensitivity because aromatic hydrocarbons were selectively partitioned into the yolk thus reducing availability of the hydrocarbons to the embryo and resulting in lower toxicity.

Although eggs take up hydrocarbons at a slow rate, they may accumulate lethal levels of hydrocarbons during long-term exposures and, therefore, would be more sensitive to hydrocarbons than indicated by short-term experiments. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Korn, S., D.A. Moles, and S.D. Rice. 1979. Effects of temperature on the median tolerance limit of pink salmon and shrimp exposed to toluene, naphthalene, and Cook Inlet crude oil. Bull. Environ. Contam. Toxicol. 21:521-525. (ADF&G, Habitat Library, #R3687.)

A series of static 96-h tests at different temperatures was run with toluene, naphthalene, and the water-soluble fraction of Cook Inlet crude oil using pink salmon and <u>Eualus</u> shrimp. The 96-h median tolerance limit (TLm) of pink salmon exposed to toluene was significantly lower at 4° than at 12°C. The 96-h TLms for shrimp exposed to toluene and naphthalene were significantly higher at 4°C than at 12°C. Other tests were not significant. They concluded that temperature affects the sensitivity of oil components to pink salmon and shrimp in a nonuniform way and that the effect should be tested for each component with each organism. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in water temperature; change in levels of hydrocarbons.

Korn, S., S.D. Rice, D.L. Chetham, and D.W. Brown. In press. Contribution of phenol, and p-cresol to the toxicity of crude oil to (Oncorhynchus gorbuscha) fry and kelp shrimp (Eualus suckleyi). In W.B. Vernberg, A. Calabrese, F.P. Thurberg, and J.F. Vernberg, eds. Symposium on pollution and physiology of marine organisms, Mystic, Conn., Nov. 1983, Univ. South Carolina Press. (ADF&G, Habitat Library, #R3688.)

Although aromatic hydrocarbons are presumed to be the major contributors to the toxicity of oil-water solutions, the quantitative contribution of nonaromatic and aromatic compounds is undocumented. The objective of this research is to measure the contribution of the highly water-soluble phenolic compounds to toxicity of water-soluble fractions (WSF) of oil.

Phenol and p-cresol do not contribute greatly to the toxicity of the WSF probably because concentrations of phenols in the WSF are low, their toxicity is relatively low, and the relatively low accumulation and rapid depuration of phenol and cresol compared with the important oil aromatic hydrocarbons, toluene and naphthalene.

Phenol and phenolic compounds were found in the WSF of Cook Inlet crude oil at concentrations of 0.013-0.092 ppm. The acute toxicity of phenol and cresol to pink salmon was 3.73 and 3.36 ppm, respectively, and with shrimp, 10.31 and 7.36 ppm, respectively. Salmon and shrimp accummulated 11-22 times the initial exposure concentration of phenol and cresol in 24 h. Both compounds were eliminated rapidly with residues being undetectable after 7 d or less. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Koski,K V., and R.A. Walter. 1977. Forest practices in relation to management of Alaska's coastal zone resources: a review with management and guidelines recommendations. State of Alaska, Office of Coastal Management, Juneau. 187 pp. (ADF&G, Habitat Library, #B1299.)

This report contains sections on the impacts of silvicultural activities on freshwater and marine environments. Impacts discussed for freshwater environments include inorganic sediment, organic debris, temperature, overhead and bank vegetation, streamflow, stream morphometry, dissolved oxygen, nutrient leachates, and forest chemicals. Impacts discussed for the marine environment include hydrographic changes; crushing, compaction, and battering of sediments and shorelines; input of bark and other debris, siltation, increased turbidity, dissolved oxygen reduction, and input of leachates.

Activity: chemical application; clearing and tree harvest; grading/plowing; log storage/transport; processing lumber/kraft/pulp.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; change in level of dissolved oxygen, nitrogen; change in levels of chlorinated compounds; change in levels of biocides; change in levels of other toxic compounds - bark or log leachates; change in levels of other toxic compounds - other; change in levels of nutrients.

Koski, K V., J. Heifetz, S. Johnson, M. Murphy, and J. Thedinga. 1984. Evaluation of buffer strips for protection of salmonid rearing habitat and implications for enhancement. Pages 138-155 in T.J. Hassler, ed. Proceedings: Pacific Northwest Stream Habitat Management Workshop, 10-12 October, Humboldt State Univ., Arcata, CA. (ADF&G, Habitat Library, #R3421.)

Effectiveness of buffer strips in protecting rearing habitat of juvenile salmonids from the effects of logging was evaluated by comparing habitat and fish population density in old-growth, buffered, and clear-cut reaches of streams. In summer, buffered and clear-cut reaches had more algae, benthos, and, as a result, more salmonid fry (age 0) than old-growth reaches. Densities of parr (age 1 and older) in summer were higher in the buffered reaches than in either the clear-cut or old-growth reaches. In winter, old-growth and buffered reaches contained the most critical habitat (i.e., pools with cover) and had the highest densities of parr. Clear-cut reaches had the least amount of debris, pool habitat, and, consequently, fewer parr than either buffered or old-growth reaches. Logging with buffer strips appears to enhance fish production by increasing fry recruitment in summer while sustaining survival of parr in winter. (Authors' abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation.

Kraft, M.E. 1972. Effects of controlled flow reduction on a trout stream. J. Fish. Res. Bd. Can. 29:1405-1411. (ADF&G, Habitat Library, #R5102.)

The total number of brook trout age 1 and older in three runs of Blacktail Creek, Montana, was reduced approximately 62% when 90% of the normal flow was diverted for about 3 mo, in comparison with 20% for runs in control sections. Both number and weight of trout in pools of the test sections generally increased, whereas those in control pools decreased. Recaptures of tagged trout also indicated movements from runs to pools in the text sections, but not in the control sections. When the flow was reduced 75% or less, there were no consistent changes in number or weight of trout in the test runs and pools, whereas those in the control sections were more marked though also inconsistent. Reduced flows had to consistent effect on the number of underyearlings. The changes in most physical characteristics after 90% flow reduction were considerably less than the degree of reduction, presumably because the stream flowed in a well defined channel. Surface area and average depth where least affected (about 42% decrease) and current velocity (75%) the most. Fast-water portions (current velocity over 0.30 m/sec) comprised over 60% of the surface area at normal flows and slow water portions over 85% of the area when the flow was reduced 90%. A multiple linear regression with the physical characteristics as independent variables and the number of trout as the dependent variable accounted for over 75% of the variation in the number of age 1 and older trout in runs and pools. (Author's abstract)

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water.

Kramer, R.H., and L.L. Smith. 1965. Effects of suspended wood fiber on brown and rainbow trout eggs and alevins. Trans. Am. Fish. Soc. 94(3):252-258. (ADF&G, Habitat Library, #R4692.)

Under laboratory conditions, rainbow trout (Salmo gairdneri) and brown trout (Salmo trutta) were hatched and held in continuous-flow suspensions of conifer groundwood fiber. Groundwood pulp was composed of approximately 75% spruce (Picea marianai and P. glauca) and 25% balsam fir (Abies balsemea).

Suspended conifer groundwood fiber has significant effects on the survival, vital function, and growth of brown and rainbow trout alevins. Fiber clogs the buccal (mouth) and gill cavities and induces sufficient stress to kill a high proportion of alevins from 24 to 48 h after hatching. Surviving alevins had reduced breathing rate, heart rate, respiration rate, and growth rate. The lowest fiber level tested (60 ppm) caused significant sublethal responses. Approximate doubling of the fiber concentration to 125 ppm resulted in a small and usually nonsignificant change in effect, but doubling again to 250 ppm caused a large and significant increase in nearly all cases. After alevins were removed from the fiber, those from the 60- and 125-ppm-fiber treatments appeared to recover and grew as fast or faster than the controls. Alevins removed from 250-ppm-fiber suspensions appeared to have suffered some permanent effects from fiber exposure, inasmuch as the rate of juvenile growth continued to be slow for 91 d. Concurrent bioassays with 88 parts per billion Metasol-L indicated that the effects observed were not related to possible residual concentrations of this slimicide, which was added to pulp at the mill.

Trout alevins remain on the bottom for a number of days after hatching. They may be extremely susceptible to wood-fiber pollution in natural waters because suspended fiber tends to settle to the bottom. Eggs appear to be invulnerable to mechanical effects of suspended wood fibers, and fish hatched from eggs incubated in fiber did not show any debilitating effects that were reflected in their growth rates. Any deleterious effects of fiber on eggs in natural waters would appear to be derived from chemical or biological characteristics of fiber sludge beds, which would cover bottoms where eggs had been deposited.

Activity: clearing and tree harvest; processing lumber/kraft/pulp.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

Krygier, J.T., and R.D. Harr. 1972. Changes in storm hydrographs due to roadbuilding and clearcut logging on coastal watersheds in Oregon. Water Res. Inst., Proj. No. A-001-ORE, Oregon State Univ., Corvallis. 49 pp. (ADF&G, Habitat Library, #B1744.)

The purpose of this study was to establish the significance of changes in storm hydrographs occurring as a result of roadbuilding and clear-cut logging. Experimental watersheds in the Oregon Coast Range, including a control, were used to evaluate kinds of hydrograph changes associated with timber harvesting. Studies of runoff processes do indicate that storm hydrographs may be modified where surface runoff is generated or where the amount of soil water is increased by a reduction in evapotranspiration. The magnitued of the hydrograph response is related to the extent of soil disturbance that decreased infiltration, the degree of vegetation removal, the existing soil depth, increased runoff efficiency and other variables. The combined and separate treatments tested among three watersheds in the Alsea River drainage were 1) roadbuilding; 2) nearly complete clear-cutting without burning or roads; 3) nearly complete clear-cutting with roads and high-intensity burning; 4) smaller patch clear-cuts with roads; 5) combined roads and clear-cutting in a large watershed, including subwatersheds and other roads; and 6) clear-cut with a medium intensity burn. The hydrograph variables of storm response that were evaluated for change were instantaneous peak discharge, time-to-peak, and quick, delayed, and total flow volumes.

Construction of roads in the Alsea forested watersheds led to an increase in peak discharge as much as 50% in the fall months and 21% in winter. No volume changes from road construction were detected among the watersheds. The influence of roads on peak discharge at the outlet of a larger watershed was not detectable. Clear-cutting without effects of roads and slash burning induced changes in peak discharge of 128% for all months and 22% for the winter "recharged" period. Clear-cutting increased peaks by 90% in fall and 28% in winter. The results of this study cannot be extrapolated to peak discharges beyond a 10-yr return period.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water.

Kuenzler, E.J., P.J. Mulholland, L.A. Ruley,and R.P. Sniffen. 1977. Water quality of North Carolina coastal plain streams and effects of channelization. USDI, UNC-WRRI-77-127. 160 pp. (ADF&G, Habitat Library, #B1807.)

A study was made of the physical and chemical characteristics of seven small coastal plain streams of eastern North Carolina. Three natural streams that flow through relatively undisturbed bottomland hardwood forests were compared to four streams that had been channelized for the purpose of reducing agriculatural losses caused by flooding. Two or three sampling stations were established on each stream. Some stations on natural streams were essentially pristine but others received point-source inputs of livestock farm wastes. The natural streams had broad floodplains and low stream velocities even during flood stages. Spates occurred in all seasons, but high discharge, and concomitant flooding of natural swamps, were usually greatest during winter and spring. The waters of channelized streams, however, were restricted; they attained higher velocities, carried greater particulate loads, and were more turbid than natural streams. Some channelized streams were enriched by sewage, by livestock wastes, or by agricultural fertilizer. (Author's abstract: partial)

Activity: channelizing waterways; grazing.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; change in levels of nutrients.

LaPerriere, J.D., D.M. Bjerklie, R.C. Simmons, E. Van Nieuwenhuyse, S.M. Wagner, and J.B. Reynolds. 1983. Effects of gold placer mining on interior Alaskan stream ecosystems. Pages 12-1 to 12-34 in J.W.Aldrich, ed. Proceedings: managing water resources for Alaska's development. Institute of Water Resources, Univ. Alaska, IWR105, Fairbanks. (ADF&G, Habitat Library, #R3956.)

During the summers of 1982 and 1983, studies were conducted on the effects of placer mining on water quality and the ecology of streams in interior Alaska, northeast of Fairbanks. The studies involved two sets of paired watersheds, one undergoing active mining, the other a control. Increased suspended sediments that settled out downstream cemented the streambed, causing the surface and groundwater flow to be isolated. As a result, the water chemistry of the mined streams was different from that of the unmined control. Mined streams experienced lower hardness, alkalinity, and specific conductance. Mined streams had higher concentrations of settleable solids, turbidity, and heavy metals.

Benthic algae were severely reduced in mined streams; the reason for this was not pursued. Benthic macroinvertebrates, mostly aquatic insects, were also reduced in numbers and species. Although the unmined streams contained many arctic grayling, no grayling were found in the mined streams when mining produced heavy loads of suspended materials. An exception to this occurred during fall out-migration, when grayling were running to overwintering grounds in the larger rivers. Cage experiments in mined streams demonstrated that grayling suffer physiological harm, including reduced feeding, slowed maturation, and gill damage. It is concluded that placer mining sedimentation severely reduces the aquatic life in heavily mined interior streams and results in a reduced biological carrying capacity of the affected watersheds.

Activity: dredging; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in levels of pH, alkalinity, or hardness; change in levels of heavy metals.

Land, B. 1974. The toxicity of drilling fluid components to aquatic biological systems: a literature review. Fish. Mar. Serv. Res. Dev. Tech. Rept. 487. 33 pp. (ADF&G, Habitat Library, #B1833.)

This report is a literature review and summary on the toxicity to aquatic biological systems of drilling fluid components used in northern Canada. This review includes aquatic toxicity literature that was available prior to January 31, 1974. The components of drilling fluids include suspended solids, chlorides, alkaline sources, chromium compounds, bactericides, organic polymers, dispersents, defoamers, lubricants, and detergents. The suspended solids include calcium sulfate, barium sulphate, bentonite day, and wood fibers. On the basis of quantities used and of the harmful long-term effects produced, the alkaline sources, bactericides, barium sulphate, bentonite, chromium salts, and potassium chloride compromise the major sources of aquatic toxicity. (Author's abstract: modified)

Activity: drilling.

Impact: change in levels of heavy metals; change in levels of chlorinated compounds; change in levels of biocides; change in levels of other toxic compounds - other.

Lantz, R.L. 1971a. Guidelines for stream protection in logging operations. Oregon State Game Commission, Research Division, P.O. Box 3503, Portland, Oregon 97208. 29 pp. (ADF&G, Habitat Library, #B0423.)

The author explains that this publication is an attempt to outline a practical basis for the management of coastal watersheds for the continued production of timber, fish, and high-quality water. By protecting streamside vegetation and minimizing sources of sedimentation through careful planning, these resources can be produced at the same time in the same watersheds.

The guidelines listed in this pamphlet were developed as a result of the Alsea watershed research program and related studies. Areas included in the guidelines are a general category of cutting and yarding techniques, road location and design, road construction, and road maintenance. This publication is a valuable source of guideline information.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Lantz, R.L. 1971b. Influence of water temperature on fish survival, growth and behavior. Pages 182 - 193, in, J.T. Krygier and J.D. Hall (eds.), Proc. of a symposium on forest land uses and stream environment. October 19-21, 1970. Oregon State Univ., Corvallis, OR. (ADF&G, Habitat Library, #R5208.)

Water temperature can control the functions and activities of freshwater fishes since their body temperature is similar to the temperature of their environment. The removal of streamside vegetation during logging operations can increase water temperatures. Such temperature increases would be most significant on small streams, which are essential to the production of salmon and trout in the Pacific Northwest. A general technical review of the effects of temperature on fish survival, growth, and behavior is presented. Concepts regarding the thermal requirements of fishes are summarized. Buffer strips of vegetation along streams are suggested as an important land management tool. In addition to eliminating or minimizing water temperature increases, buffer strips serve other purposes and provide for true multiple-use of the resources of our watersheds. (Author's Abstract).

Activity: clearing and tree harvest.

Impact: change in water temperature; alteration of natural cover - riparian vegetation.

Larse, R.W. 1971. Prevention and control of erosion and stream sedimentation from forest roads. Pages 76-83 in J.T. Krygier and J.D. Hall, eds. Proceedings Symposium on Forest Land Uses and Stream Environment, October 19-21, 1970. Oregon State Univ., Corvallis. (ADF&G, Habitat Library, #R5085.)

To minimize erosion and resultant stream sedimentation, prevention and control measures must be given consideration in every aspect of road planning, design, construction, and maintenance. In mountainous terrain, the forest land manager must establish specific objectives and prescriptions to guide road network construction and utilize the combined professional skills of the forester, engineer, geologist, biologist, and others to set standards for the protection of watershed values, identify alternatives, and offer solutions to specific problems.

The decision to road an area should be made only after the resource-serving benefits have been carefully weighed against the cost and effect of roading on the watershed. The decision not to road and to accept other alternatives for land-use management must be strongly considered when the probability of lasting damage to soil, water, and other ecological values is recognized. (Author's abstract)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments.

Laseter, J.L., G.C. Lawler, E.B. Overton, J.R. Patel, J.P. Holmes, M.I. Shields, and M. Maberry. 1981. Characterization of aliphatic and aromatic hydrocarbons in flat and Japanese type oysters and adjacent sediments collected from l'Aber Wrac'h following the Amoco Cadiz oil spill. In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, internatioal symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4331.)

Cultured oyster (Japanese and flat types) collected serially at a commercial site in l'Aber Wrac'h approximately 3 and 13 mo after the Amoco Cadiz oil spill were charcterized by glass capillary gas chromatography $(GC)^2$ MS techniques for their petroleum hydrocarbon content.

Total hydrocarbons in each fraction for both the cultured Japanese and flat oysters, collected 3 mo follwoing the spill, were 10-20 times higher than for control oysters collected at the same time from a commercial source at Loc Tudy. The total hydrocarbon content of the Japenese type oysters at l'Aber Wrac'h was slightly less at 13 mo than at 3 mo after the spill, whereas much lower concentrations were found in the tissues of the flat type oysters collected at the 13-mo interval. Sediments collected adjacent to the oysters showed a marked decrease in total hydrocarbon during the same period.
(Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Lawrence, M., and E. Scherer. 1974. Behavioural responses of whitefish and rainbow trout to drilling fluids. Fish. Mar. Serv. Res. Dev. Tech. Rept. 502, 47 pp. (ADF&G, Habitat Library, #B2094.)

Behavioral responses of whitefish (Coregonus clupeaformis) and rainbow trout (Salmo gairdneri) to drilling mud (1 to 1,000 ul/l) and its supernatant fraction (55 to 10,000 ml/l) were tested in laboratory experiments. Experiments were run under infrared, as well as under visible light, to separate photically from chemically elicited reponses.

Four response parameters were recorded and analyzed: 1) percentage of test time spent in pure compared to contaminated water, 2) effect of contact with contaminant on swimming speed, turning rate, and frequency of movements across the centerline of the test chamber (boundary between pure and contaminated water), 3) extent of penetration by fish into pure versus contaminated water, 4) time spent at the end walls of the pure versus contaminated water side.

Whitefish. Under incandescent light, whitefish were increasingly attracted to mud suspensions, with increasing concentration over the range tested.

Under infrared lighting, time spent in pure water increased over that observed under visible light; i.e., visually perceived turbidity was one causal element in attracting whitefish.

Whitefish also demonstrated a preference for the supernatant, up to a concentration of 1,000 ul/l, with a tendency toward avoidance at higher concentrations.

Rainbow. The percentage-time response was neutral at relatively low concentrations of suspended mud (100 ul/l), shifting to a preference at 1,000 ul/l.

The response to supernatant was similar to that of whitefish: no response at 55 ul/l, preference at 1,000 ul/l, avoidance at 10,000 ul/l.

Both whitefish and rainbow trout showed preference for mud suspensions at the maximum concentration tested, namely 1,000 ul/l; this value represent 0.04 and 0.013 of the 96-h LC_{50} for whitefish and rainbow trout, respectively. In tests with supernatant, both species showed a shift in reaction from preference at 1,000 ul/l toward avoidance at 10,000 ul/l. These two values equal 0.02 and 0.2 of a concentration still found to be nonlethal to whitefish in a static bioassay lasting 28 d. (Author's summary: modified)

Activity: drilling.

Impact: change in turbidity or suspended sediments; change in levels of other toxic compounds - other; artificial attractant to biological organisms.

Le Moal, Y., and M. Quillien-Monot. 1981. Etudes des populations de leurs juveniles sur les plages des Abers Benoit et Wrac'h. (Study of macrofauna populations and their young on the beaches of Abers Benoit and Wrac'h.) In Amoco Cadiz, Fates and effects of the oil spill, Brest, France, 1979. (ADF&G, Habitat Library, #R4334.)

After the Amoco Cadiz oil spill, the ecology of a soft-bottom intertidal fauna was investigated from November 1978 on four beaches at the entry of Abers Benoit and Wrac'h (Nord Finistere).

There were two parts to this work: first, the study of macrofauna washed through a 1-mm mesh screen and second, the study of temporary meiofauna and Annelids and "Tanaidaces" of permanent meiofauna. These samples were washed through a 0.200-mm screen. Density variations in the most important meiofauna species were studied on two beaches from November 1978 to August 1979. Some of the original macrofaunal populations were still not present more than 1 yr after the oil spill. These had been replaced by Capitellid and Cirratulid polychaetes, representing the start of an ecological succession. (Authors' abstract. Article in French)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Leedy, D.L., and L.W. Adams. 1982. Wildlife considerations in planning and managing highway corridors. Offices of Research and Development, Fed. Highway Admin., U.S. Dept. Transportation. Rept. No. FHWA-TS-82-212. 93 pp. (ADF&G, Habitat Library, #B6511.)

This manual is a guide and information source for biologists, environmental specialists, and highway personnel concerned with route selection, design, construction, operation, and maintenance of the nation's highways. The manual serves as an information source on highway-wildlife relationships and effects; provides information sources and "how to" guidance for inventorying wildlife populations, assessing environmental impacts, and evaluating habitat; suggests ways of incorporating wildlife values into highway planning; and offers suggestions for managing wildlife populations within the highway right-of-way. The manual is organized to facilitate location of specific topics. (Authors' abstract)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments.

Lees, D.C., and J.P. Houghton. 1980. Effects of drilling fluids on benthic communities at the Lower Cook Inlet C.O.S.T. well. Pages 309-346 in Research on environmental fate and effects of drilling fluids and cuttings. Symposium proceedings. Vol. 1, January 21-24 1980. Lake Buena Vista, Florida. 690 pp. (ADF&G, Habitat Library, #R5036.)

The primary objectives of these studies were to evaluate the dispersion of drilling effluents and cuttings in the receiving waters and to determine the impact of the discharges on commercially and ecologically important Alaskan species and on local benthic communities. Some changes in benthic communities were seen near the drilling vessel during the course of the study. However, no statistically significant differences could be attributed to the effects of drilling operations because of patchiness in faunal distributions. It appears that rates of accumulation of drilling muds and cuttings on the bottom in a dynamic environment such as found at the well site are not great enough to measurably affect benthic populations.

Activity: drilling; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in levels of hydrocarbons.

Lees, D.C., D.E. Erikson, W.B. Driskell, and M.S. Treesh. 1981. Biological investigations of Homer Spit coastal area. Dames and Moore, Anchorage, AK. (ADF&G, Habitat Library, #B0885.)

This study examined several aspects of the biology of selected components of the biota associated with the marine environment on and around Homer Spit. It was designed to provide an information base to assist in making environmental decisions during the evolution of coastal development policies and plans. Due to budgetary constraints, the study was limited to species having pertinent commercial importance (crab, shrimp, salmon), sport species (clams and mussels), marine birds, and some of the species lower in the food chain that are important to the well being of the above-mentioned animals (e.g., forage fishes and infaunal forage species such as clams and marine worms).

The major concern was that the areas surrounding the Homer Spit might be important rearing, nursery, and feeding areas for certain commercial and sport species and marine birds, and that anticipated development could reduce the quality, and thus productivity, of these areas. Thus a major study objective was to assess the importance of the habitats and activities and define the manner in which these habitats, activities, and the associated resources are susceptible to development. A general study objective was to identify potentially limited habitats of importance so that measures can be taken to avoid development impacts until additional information regarding importance or sensitivity can be obtained.

Field studies were conducted in 1980-81 at 84 sites along 16 transects in intertidal and subtidal habitats within one-half mile of the mean high tide line on both sides of Homer Spit. Study objectives were to 1) map and describe all major substrate types; 2) describe epifloral, epifaunal, and infaunal species assemblages and associations by habitat, location, season, and zonation; 3) describe the occurrence and relative abundance of the larval stages of commercially important species of crustaceans; 4) describe the occurrence and relative abundance of young salmonids; 5) determine the occurrence of beaches that are used by capelin and other pelagic marine fishes for spawning; 6) describe seasonal habitat use and temporal and spatial distribution of waterbirds; 7) evaluate the potential biological impacts within the study area from development activities on Homer Spit.

Activity: filling and pile-supported structures (aquatic and wetland habitats); solid waste disposal.

Impact: change in level of dissolved oxygen, nitrogen; introduction or removal of species.

Leglise M., and G. Raguenes. 1981. Suivi des effets du naufrage de l'Amoco Cadiz sur les crustaces commercialisables dans la zone polluee. (Study of the effects of oiling from the Amoco Cadiz on commercial crustaceans in the polluted zone.) In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4333.)

The edible crustaceans, lobsters, spiny lobsters, edible crabs and spider crabs, of the polluted area were studied between April 1978 and July 1979. Information was obtained by fishing sheets and survey with professional boats. During 1978, only experimental fishing operations were made. The catches between the west of Batz Island and Tremanzan had a taste of oil. The rate of oil was low in the flesh but higher in the liver. Since May 1978, it has been possible to fish everywhere. There is concern about the abnormally low rate of gravid female lobsters near Portsall. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Lehmann, E.J. 1975. Sewage effects in marine and estuarine environments: a bibliography with abstracts. National Technical Information Service NTIS/PS-75/430. (ADF&G, Habitat Library, #B0969.)

This bibliography contains 136 selected abstracts of research reports from 1964 to 1975. The topics cover the effects of sewage effluents and sludge upon marine and estuarine environments and especially on their ecology. Included are reports dealing with the effects on marine plants and animals, problems due to ocean dumping, dispersion studies, water chemistry, and other related topics. (Author's abstract)

Activity: sewage disposal; solid waste disposal.

Impact: change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of chlorinated compounds; change in levels of nutrients.

Lenat, D.R., P. Eagleson, and K.W. Eagleson. 1981. Variable effects of sediment addition on stream benthos. Hydrobiologia 79:187-194. (ADF&G, Habitat Library, #R3758.)

Two upper Piedmont streams were studied to determine the effects of road construction, especially sediment inputs. Both streams are located in agricultural areas, receiving surface runoff from farmland and rural dirt roads. Each stream also crosses a major highway which was being widened from two to four lanes. Several management practices designed to minimize erosion were employed but they were often poorly installed or maintained. Cleared areas were reseeded, but "cut-and-fill" portions often remained bare for periods of several months. These areas often experienced severe erosion, often developing deep gullies. Silt fences and sedimentation basins were used but were often improperly placed or not maintained. Fill areas (near culverts) eroded badly; likewise, excavated spoil often was allowed to wash back into the streams. A segment of one stream was rechannelized in late summer. No rip-rap was used to protect the new channel prior to a flood that severely eroded the area, enlarging the channel to three times its original width.

Limited sampling of pH, temperature, and dissolved oxygen suggested no significant changes.

Benthic macroinvertebrate data suggest that the stream community responded to sediment additions in two different ways. The reaction of the benthic community is dependent on the stability of sand substrates which is, in turn, dependent on flow. Under low flow conditions, a stable-sand community developes that is composed of small grazing organisms capable of rapid colonization and reproduction.

During high periods, sand substrates become an unsuitable habitat for all benthic organisms. Sediment addition reduced available hatitat area. The remaining community is similar to that of unstressed areas but has a markedly lower density.

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

Lestelle, L.C., and C.J. Cederholm. 1984. Short-term effects of organic debris removal on resident cutthroat trout. Pages 131-140, In, W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley, eds. Fish and wildlife relationships in old-growth forests. Proceedings Symposium, Juneau, AK, 12-15 April 1982. (ADF&G, Habitat Library, #R5138.)

Excessive cleanup of logging residues along small streams can deplete the stream environment of large, stabilized organic debris. An experiment was conducted to determine the effects on a resident salmonid population of overcleaning a stream course of organic debris. The study was conducted in two headwater streams of the Clearwater River in Washington during 1972 and 1973. Clearing of the stream had little or no effect on numbers and biomass of cutthroat (Salmo clarkii clarkii) immediately after alteration and prior to winter. Subsequently, population reductions occurred in the treated stream over winter 1972-1973, but these losses were short-term. The decline in numbers of overwintering trout was apparently associated with habitat instability brought on by the removal of large organic debris from the stream channel. Within 1 yr of debris removal, the cutthroat trout population had returned to pretreatment levels. Also, the physical habitat characteristics of the altered stream were largely restored to pretreatment conditions within 1 yr of debris removal. If there had not been a source of debris to replace that which was removed, habitat and fish recovery may have been slower. (Authors abstract)

Activity: clearing and tree harvest.

Impact: alteration of natural cover - aquatic vegetation.

Lett, P.F., G.J. Farmer, and F.W.H. Beamish. 1976. Effect of copper on some aspects of the bioenergetics of rainbow trout (Salmo gairdneri. J. Fish. Res. Bd. Can. 33:1335-1342. (ADF&G, Habitat Library, #R4367.)

The influence of sublethal concentrations of total copper on the appetite, growth, and proximate body composition of rainbow trout (Salmo gairdneri) held in hard water (365 mg/l) was measured over a 40-d interval. The initial response of trout exposed to concentrations of copper ranging from 0.0 to 0.3 mg/l (the 96-h LC_{50} was 0.25-0.68) was the cessation of feeding. However, within 15 d, food intake returned to amounts observed for control fish, the rate of return of appetite being dependent on copper concentration and ration level. Growth rate of trout exposed to copper (0.075-0.225 mg/l) and fed rations of either 0.25 or 1.5% dry food wt/wet fish wt per day was initially depressed but approached values observed for control fish near the end of the 40-d interval. During this period, lipid, protein, and moisture of fish exposed to copper did not change significantly. Initially, growth retardation was not attributable to the inability of copper-exposed fish to digest their daily rations. The authors conclude that if fish are not killed by copper, they can acclimate at least to copper concentrations of 0.50 the LC_{50}. If, as in this study, copper is the only stressor or concern, the authors propose that on the basis of the growth response of rainbow trout, a copper concentration of 0.10 the LC_{50} "seems" to be a sufficiently safe level for a water-quality standard. (Author's abstract: modified)

Activity: processing minerals.

Impact: change in levels of pH, alkalinity, or hardness; change in levels of heavy metals.

Linden, O. 1978. Biological effects of oil on early development of the Baltic herring *Clupea harengus membras*. Mar. Biol. 45:273-283. (ADF&G, Habitat Library, #R3895.)

The effects of petroleum hydrocarbons from two crude oils and No. 1 fuel oil were studied on the development of Baltic herring (*Clupea harengus membras L.*). Herring eggs exposed to water soluble fractions of the oils at fertilization showed no decrease in numbers of fertilized eggs compared to eggs exposed 6 or 72 h after fertilization. During embryogenesis, treatment with hydrocarbons from the oils gave rise to changes in embryonic activity, decreased heart rate, and premature or delayed hatching. Although many larvae hatched from eggs exposed to contaminated water, 70 to 100% of them were malformed or dead 1 d after hatching. Exposure of eggs to oil also resulted in decreased lengths of the larvae. Temperature increases from 9 to 14°C aggravated the effects of the oils.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in water temperature; change in levels of hydrocarbons.

Lister, D.B., and C.E. Walker. 1962. The effect of flow control on freshwater survival of chum, coho, and chinook salmon in the Big Qualicum River. Department of Fisheries of Canada, Resource Development Branch, Vancouver, B.C. 25 pp. (ADF&G, Habitat Library, #R2917.)

An environmental control project was undertaken on a British Columbia stream to increase the production of native chum, coho, and chinook salmon populations. The equipment constructed provided for stabilization of winter flows, increase in the minimum summer flow, and a degree of temperature control during summer and early fall. The freshwater survival rate of each species during a 4-yr period of natural flow conditions is compared with that resulting from the first 2 yr of controlled flow. Chum salmon egg-to-fry survival ranged from 5 to 17% under natural conditions and was inversely related to peak daily discharge during the incubation period. Survival rates in the 2 yr of flow control were 25.2% and 24.5%, respectively. The magnitude of the coho fry emigration near the river mouth was also related to winter discharge stability. Coho spawning populations of similar size, but affected by differing incubation conditions, produced fry emigrations amounting to 0.3% (natural flow) and 4.3% (controlled flow) of their respective egg potentials. Little variation occurred in coho smolt output over a 5-yr period. Chinook salmon survival ranged from as low as 0.2% under natural conditions to 19.8% in 1 yr of controlled flow. The largest production of chinook emigrants was accompanied by a substantial change in qualitytoward smaller size and earlier migration timing. (Author's abstract: modified)

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water.

Little, A.D. 1973a. Report on channel modifications. Prepared for the Council on Environmental Quality, Vol. 1. (ADF&G, Habitat Library, #B1892.)

This report is the first volume of a two-volume set of information presented to the Council on Environmental Quality of the Executive Office of the President of the United States. It assesses environmental, economic, financial, and engineering aspects of channel modifications and the availability and use of alternatives as planned and carried out by the Corps of Engineers, Soil Conservation Service, Tennessee Valley Authority, andBureau of Reclamation. The assessment has drawn upon the publicrecord and literature, observations in the field of 42 projects in 18 states, and discussions with at least 558 people in 30 public meetings throughout the nation.

The report is partitioned into nine chapters, of which two pertain to physical and biological effects of channelizing on aquatic biota or their habitats. The report is quite comprehensive and is a good objective summary of channelizing effects.

Activity: channelizing waterways; draining.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Little, A.D. 1973b. Report on channel modifications. Vol. II. U.S. Council on Environ. Qual., Wash. D.C., U.S. Government Printing Office, Washington, D.C. 1973. (ADF&G, Habitat Library, #B1892.)

This document is a compilation of 42 Field Evaluation Reports of channel modification projects conducted in several different states in the continental United States. The reports are based upon data obtained from a variety of sources. However, most of the definitive facts available for each project were supplied by the agency whose construction works were being evaluated. The reports reflect this situation. In spite of this, the biological evaluation of most of the projects provides useful information on types of observable negative effects resulting from channelization. In many cases the relative magnitude of effects are estimated, based on pre-project data (if available) or by comparing the biological community in channelized reaches to nearby, undisturbed reaches. Most biological assessments consider algae, macrophytes, invertebrates, and fish.

Activity: channelizing waterways; draining.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Lloyd, D.S. 1985. Turbidity in freshwater habitats of Alaska. A review of published and unpublished literature relevant to the use of turbidity as a water quality standard. AK Dept Fish and Game, Habitat Division, Rept. No. 85-1. 101 pp. (ADF&G, Habitat Library, #B5031.)

Turbidity is an optical property of water, wherein suspended sediments and other material in the water scatter and absorb light. Turbidity measurements can be used to estimate both the penetration of light into a body of water and the concentration of suspended material in water. The value of water quality standards based upon specific turbidity criteria has been questioned, and the Alaska State Water Quality Standards (18 AAC 70) are currently being reevaluated. This paper attempts to outline relationships between turbidity and a suite of parameters that are most relevant to sustained increases of turbidity in clear-water systems. Specifically, examples from recent studies performed in Alaska, and elsewhere, provide ample illustration that turbidity criteria can be used as reasonable and effective water quality standards which, if implemented, can prevent or ameliorate the following adverse effects caused by suspended sediments in water:

1. Extinction of light in lakes and streams
2. Reduction or loss of primary (plant) production in lakes and streams
3. Reduction or loss of secondry (zooplankton and aquatic insect) production in lakes and streams
4. Reduction or loss of fish production in lakes and streams
5. Reduction in recreational fishing use of streams
6. Reduction in efficiency of fishery management techniques

Furthermore, because turbidity can be directly related to the concentration of suspended sediments in water, with adequate data predictive relationships between turbidity and suspended sediment concentrationn can be developed. This type of relationship can allow for the use of turbidity standards to address and regulate the direct physical effects of suspended material on aquatic life, which have also been described in available literature.

<u>Productivity in Lakes</u>

Studies conducted by the Alaska Department of Fish and Game (Koenings 1984) on the production of sockeye salmon in lakes provide the following information on clear and naturally turbid (glacial) lakes, i.e., lakes ranging in turbidity from approximately 0 nephelometric turbidity units (NTU) to an average of approximately 52 NTU:

1. Increases in burbidity from 0-1 NTU to approximately 10 NTU cause a dramatic reduction in the depth to which one percent of available surface light penetrates into water. Such compensation depths for clear-water lakes were measured at approximately 16-17 meters, while compensation depths for

lakes with turbidity of between 2-10 NTU were measured at only 2-6 meters. The compensation depth for a lake averaging 52 NTU occurred at less than 1 meter. A 5 NTU increase of turbidity can reduce the productive volume of a clear-water lake by approximately 75 percent.
2. Abundance of zooplankton in naturally turbid lakes was observed to be lower than that in clear-water lakes. Moreover, abundance of preferred food items (Cladocera) for juvenile sockeye salmon was observed to be dramtically reduced in turbid lakes.
3. Production of juvenile sockeye salmon and returns of adult sockeye salmon were observed to be lower in turbid lake systems than in clear- water lake systems.

A study conducted by R&M Consultants (1982b) also compares the extinction of light and turbidity in a glacial lake. The results describe a similar dramatic reduction in light penetration with small increases of turbidity above 0-1 NTU.

Productivity in Streams

Studies conducted by the University of Alaska-Fairbanks (LaPerriere et al. 1983, Van Nieuwenhuyse 1983, LaPerriere 1984, Simmons 1984, Wagener 1984) describe the following set of adverse effects associated with human-induced turbidity and sedimentation in clear-water streams:

1. Light penetration is reduced by turbidity, and light extension is directly related to turbidity.
2. Primary production in streams is reduced or eliminated by turbidity. Calculations derived in this report using equations relating turbidity, ligh availability, and primary productivity indicate that a turbidity of 5 NTU may reduce primary production in a normally clear-water stream 0.5 meters (1.5 feet) deep by approximately 13%; a 25 NTU increase in turbidity over normally clear-water conditions may reduce plant production by 50%. These effects may be even more prounounced in deeper streams.
3. Abundance of macroinvertebrates in turbid and sedimented streams is much lower than that in clear-water streams.
4. Abundance of fish (arctic grayling) in turbid and sedimented streams is reduced or eliminated. Also, physiological stress is exhibited by grayling in highly turbid streams.

Observations by the ADF&G (Townsend 1983, Ott 1984b) indicate that recreational use of streams for sportfishing is reduced in normally clear-water streams when turbidity increases above 8 NTU, and that aerial survey techniques employed in the management of commercial fisheries are hampered at turbidities of 4-8 NTU and above.

Suspended Sediment Concentration

Turbidity can be directly related to suspended sediment concentration. Therefore turbidity standards can be used to control the direct physical effects of sediment on aquatic life. Using data retrieved from statewide sampling conducted by the U.S. Geological Survey (USGS 1984), we have calculated a general relationship between turbidity and suspended sediment concentration. This relationship indicates that 25 mg per liter is associated with turbidity on the order of 5 NTU and that 100 mg per liter is associated with turbidity on the order of 25 NTU. A regrission equation derived by Peratrovich et al. (1982) illustrates a similar relationship for the Susitna River. From recent data compiled from selected streams in interior Alaska (Post 1984, Toland 1984) we have calculated a more specific relationship indicating a one-to-one correspondence between turbidity in NTU and suspended sediment concentration in mg per liter.

Turbidity Standards

Based upon the information summarized in this report, derived from studies conducted in Alaska and elsewhere, the current State Water Quality Standard for turbidity to protect the propagation of fish and wildlife (25 NTU above natural conditions in streams, 5 NTU above natural lakes) may be sufficient to provide a moderate level of protection for clear-water aquatic habitats. A 25 NTU increase in turbidity in shallow clear-water systems may potentially reduce stream primary productivity by 13 to 50 percent or more, depending on stream depth and ambient water quality, and be associated with an increase in suspended sediment concentration of approximately 25 to 100 mg per liter.

A higher level of protection will require the application of a stricter turbidity standard. The standard presently applied to drinking water is 5 NTU above natural conditions in streams and lakes. A 5 NTU increase in turbidity in clear-water systems may reduce the primary productive volume of lakes by approximately 75%, reduce stream productivity by 3 to 13% or more, depending on stream depth and ambient water quality, and be associated with an increase in suspended sediment concentration of approximately 5 to 25 mg per liter. The current Interagency Placer Mining Guidelines (State of Alaska 1984) use turbidity of 3 NTU or less as a criterion to specify high priority streams. Application of a 5 NTU above ambient standard would bring total turbidities in these streams to 8 NTU, the level at which recreational fishing may decline and at or above the level at which efficiency of aerial surveys for fishery management are affected. (Executive summary)

Activity: channelizing waterways; clearing and tree harvest; dredging; grading/plowing; grazing; processing minerals.

Impact: change in turbidity or suspended sediments.

Long, E.B. 1982. An assessment of marine pollution in Puget Sound. Mar. Pollut. Bull. 13(11):380-383. (ADF&G, Habitat Library, #R3920.)

This paper presents selected findings of several research investigations sponsored by the U.S. National Oceanic and Atmospheric Administration (NOAA). Investigations for the project (titled the Marine Ecosystems Analysis Puget Sound Project [MESA] were initiated in 1978 to determine contaminant concentrations in sediments, fish, and benthic invertebrates in Puget Sound (Washington). Contaminants were found in all sampled sections of the sound. Highest concentrations were found in bays near the larger urban centers. Chlorinated organic concentrations in many areas were at levels that warranted concern relative to ecological and human health effects. Histopathological changes, hematological stress indicators, infauna recruitment, mutagenic responses, and catch statistics for demersal fish and epibenthic macroinvertebrates also were investigated.

Although contaminant concentrations were highest in industrial waterways, low levels of contaminants were found in pelagic fish far from suspected sources. Frequency of liver lesions in fish and gill and antennal gland disorders in crustaceans appeared to be greatest in areas with relatively high aromatic hydrocarbon and trace metal concentrations. Benthic infauna taxon richness and epifauna colonization rates were depressed in these same areas. Demersal fish abundance and species diversity were highest in these areas, however.

Specific effects on biota were numerous. A large variety of histopathological conditions were observed among the demersal fishes, shrimp, and crabs collected at the sites where contaminant levels were determined. These conditions included neoplasms (tumors), necroses, lesions, and other cellular disorders in fish livers; lesions and hyperplasia in fish gills; lesions in fish kidneys, skin, fin, heart, gastrointestinal tract, spleen, gonad, and gall bladder; necroses and melanized nodules and granulomas in shrimp gills; various necrotic and abnormal conditions in shrimp and crab hepatopancreas, antennal gland, bladder, and midgut; and many parasitic infestations. Many of these conditions were idiopathic, that is, their causes are unknown but not related to any visible (at the light microscope level) infectious agent. They could be caused by exposure to chemical contaminants, nutritional disorders, micro-organisms, genetic disorders, or trauma.

Although there is no direct evidence that these disorders were caused by the contaminant mixtures found where the animals were collected, statistical tests were performed to determine if there were any significant geographical trends in the frequency of disorders and any correlations between their frequency of occurrence and the concentrations of contaminants in sediments.

The results of the G-statistic test showed that the frequency of many liver lesions in rock and English sole were significantly higher (P is less than or equal to 0.05) at heavily contaminated sites and significantly lower at stations in reference areas and outer parts of the urban bays (areas of lower levels of contamination). Similar results were obtained with the gill necroses in shrimp and crabs. Next by use of the Spearman rank correlation, it was determined that the frequencies of English sole with liver neoplasms and specific necrotic lesions were positively correlated (P is less than or equal to 0.05) with the sampling sites that had relatively high sediment concentrations of aromatic hydrocarbons and metals. The frequency of 'preneoplastic' lesions in English sole was positively corrected with high aromatic hydrocarbon concentrations (P is less than or equal to 0.01).

Activity: dredging; processing oil/gas; sewage disposal; transport of oil/gas/water - water; transport personnel/equipment/material - water.

Impact: change in levels of heavy metals; change in levels of chlorinated compounds; change in levels of hydrocarbons.

Lonning, S., and B.E. Hagstrom. 1976. Deleterious effects of Corexit 9527 on fertilization and development. Mar. Pollut. Bull. 7(7):124-127. (ADF&G, Habitat Library, #R3893.)

Laboratory experiments were conducted to test the effect of the water-soluble oil dispersant Corexit 9527 on eggs and larvae of several species of sea urchins and three marine fishes (<u>Gadus morrhua</u>, <u>Plaitichthys flesus</u>, and <u>Pleuronectes platessa</u>). Corexit at concentrations of 1-50 ppm was found to cause a strong retardation in the rate of fertilization of sea urchin eggs and to interfere with cell division and differentiation in fertilized eggs. Fish eggs were tested in concentrations of 10-100 ppm, yielding results similar to those from the sea urchin experiments. In 100 ppm of Corexit, two developmental periods were observed to be particularly vulnerable to cytolysis. The first period lasts from fertilization to the beginning of gastrulation. The second period starts after hatching when the embryos have lost the protecting chorion. In both sea urchin and fish experiments, the combination of oil and Corexit proved to be more dangerous than the oil or Corexit alone. The authors conclude that the use of Corexit is not advisable and recommend further simultaneous testing of oil, dispersant and oil, and dispersant to discover whether the end products, formed by the interaction, create more problems that the oil itself. (See Canevari and Lindblom 1976 for a different opinion.)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Lopez, E., J. Leloup-Hatey, A. Hardy, F. Lallier, E. Martelly, J. Oudot, J. Peignoux-Deville, and Y.A. Fontaine. 1981. Modifications histopathologiques et stress chez des anguilles soumises a une exposition prolongee aux hydrocarbures. (Histopathological modifications and stress in eels with prolonged exposure to hydrocarbons.) In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4335.)

In eels caught in Roscoff after the contamination by hydrocarbons from the Amoco Cadiz, the following observations were made:

- In gills, we observed an abnormal proliferation of ionocytes (chloride cells) and of mucus cells together with a hypersecretion of mucus (APS +) associated to a hyperaemia and a lysis of respiratory platelets were observed.

- In ovaries, intracytoplasmic inclusions of basophilic substances probably reflected the accumulation of hydrocarbons. Nuclei of ovocytes presented some indications of pycnosis (reticulated chromatin, hypertrophied nucleoli). The necrosis of numerous follicles was accentuated after 8 mo, and provoked a complete degenerescence of many ovocytes.

- A very high stimulation of interrenal activity was observed (glandular hypertrophy, increase in the plasma level of cortisol and increase in the <u>in vitro</u> synthesis of corticosteroid by interrenal slices). After 8 mo, the glandular tissue showed some indications of exaustion. This endocrine-reaction is similar to those described after an intensive stress of long duration. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Lorz, H.W., S.W. Glenn, R.H. Williams, C.M. Kunkel, L.A. Norris, and B.R. Loper. 1979. Effects of selected herbicides on smolting of coho salmon. USEPA: Environ. Res. Lab., Corvallis, OR. (ADF&G, Habitat Library, #B2412.)

The 96-h LC_{50} values of several herbicides to yearling coho salmon, Oncorhynchus kisutch, were determined. All 96-h tests were conducted under static conditions at 10C in freshwater of alkalinity and hardness ranging from 70-83 mg/L and 85-93 mg/l (as $CaCO_3$), respectively. The herbicides acrolein and dinoseb were the most toxic of the 12 water soluble herbicides tested, having 96-h LC_{50} values of 68 and 100 mg/l, respectively. Atrazine, diquat and picloram were moderately toxic in freshwater with 96-h LC_{50} values ranging from 10-30 mg/l.

Fish exposed to Amitrole-T, diquat and paraquat in fresh water all exhibited dose-dependent effects in subsequent sea-water entry tests. The other herbicides tested produced little or no dose-related mortality when fish were challenged with sea-water. No apparent affects on the (Na,K)- stimulated ATPase activity of the gills were observed with any of the herbicides tested.

The effect of sublethal concentrations of Tordon 101, dinoseb and diquat on migratory disposition was tested by releasing herbicide-exposed salmon into a natural stream; only diquat produced a significant reduction in downstream migration.

Under normal (field) application acrolein and dinoseb could affect survival of all life stages of salmonids if water from treated irrigation ditches were released into the stream or river without sufficient holding or detoxifying time. The use of diquat at recommended treatment levels could reduce downstream migration of smolts and possibly affect their survival in sea-water. All other herbicide formulations tested appeared to have-no effect on smolting of yearling coho salmon; however, atrazine-has been shown to affect growth of young salmonids and survival of invertebrates at very low concentrations. Effects of the herbicides on other life stages of coho salmon or different formulations of the herbicides might produce considerably different results. (Author's abstract: partial)

Activity: chemical application.

Impact: change in levels of biocides.

Lotspeich, F.B. 1971. Environmental guidelines for road construction in Alaska. U.S. Environmental Protection Agency, Alaska Water Lab., 1610 GOI 09/71. 127 pp. (ADF&G, Habitat Library, #B2295.)

This report compiles and describes the best practical measures required to assure environmental protection during road construction under cold climate conditions. The author reviews important measures of road building that must be considered, such as route selection, engineering design, construction activities (earthwork, restoration, structures, and support activities), and maintenance. Also included are a section on problems of road construction in the arctic and an attachment that provides guidelines for minimizing soil erosion from highway construction.

The guidelines presented are practical but not related specifically to aquatic environments. However, the considerations mentioned have the ability to directly affect aquatic habitats.

Activity: grading/plowing; stream crossing - structures.

Impact: change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - diversions; addition of physical barriers - partial obstructions.

Lotspeich, F.B., and A.E. Helmers. 1974. Environmental guidelines for development roads in the subarctic. Nat'l. Env. Res. Center, Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, OR. 63 pp. (ADF&G, Habitat Library, #B0547.)

This set of guidelines is based on federal and state regulations that set standards to protect the total environment. Although major highway construction is under stringent regulation, pioneer type access roads such as are needed by loggers, miners, land developers, etc., have been neglected. These smaller roads frequently pose serious erosion hazards because planning, design, and construction of them is not thorough, as it is for major roads; this results in erosion, fire and insect traps, and generally unattractive roadways.

Suggestions and recommendations contained in these guidelines are for the use of operators with limited engineering and planning staffs. Although all examples of poor practices are from the vicinity of Fairbanks, all suggested treatments are taken from the literature from the conterminous United States, with some modifications for subarctic conditions. Most of these recommendations are simple in concept and, if properly applied, do prevent erosion and result in superior access roads which are esthetically pleasing. (Authors' abstract)

Activity: clearing and tree harvest; draining; grading/plowing; processing minerals; stream crossing - structures.

Impact: change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - diversions; addition of physical barriers - partial obstructions.

Luedtke, R.J., M.A. Brusven, and F.J. Watts. 1976. Benthic insect community changes in relation to in-stream alterations of a sediment-polluted stream. Melanderia 23:21-39. (ADF&G, Habitat Library, #R3812.)

A study was conducted to evaluate the physical and biological impact of four types of in-stream alterations on a northern Idaho stream. The study stream received sediment from timber harvest, mining, summer grazing and human recreation. Log-drop structures, debris jam removal, channel diversion, and gabion deflectors were tested for effectiveness in removing fine sediments.
In-stream alterations were found to be effective for increasing sediment transport, thereby improving insect and fish habitat. Changes in the benthic insect community were directly attributable to changes in streambed sediments caused by in-stream alterations.

Log-drop structures consisted of two logs placed one atop the other, positioned transversely across the stream bed. The lower log was embedded into the substrate, and both logs were set 60 cm into the banks and shored with large rocks. These structures cause significant scouring in localized areas but were found ineffective for removing fine sediment from long, low-gradient reaches in a stream.

The removal of debris jams was found to be effective for increasing sediment transport and eliminating sediment traps. Gabion deflectors were found useful for constricting stream width, thereby increasing current velocity and sediment transport.

These in-stream devices were found to aid the study stream in the removal of sediments, in benthic recolonization, and in providing general habitat improvement for most aquatic life.

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; change in turbidity or suspended sediments.

Lull, H.W. 1959. Soil compaction on forest and range lands. USDA: Forest Service. Misc. Publ. No. 768. Washington, D.C. 32 pp. (ADF&G, Habitat Library, #B1122.)

This report reviews the available literature (prior to 1959) on soil compaction as related to soil and water conservation on forest and range lands. Effects of compaction from logging activities and physical trampling by livestock and man are the primary topics discussed. In general, the degree of soil compaction is affected by the means of compaction (i.e., trampling or vehicle, etc.), the type of equipment used, the size and nature of the area disturbed, and frequency of disturbance. Specific data are presented that support the following general principals:

° The amount of compaction will depend on the degree to which the stress applied to the soil overcomes the resistance the soil offers to deformation.
° The resistance that the soil offers depends on its moisture content, texture, structure, density, and organic content.
° As this resistance is overcome, the effect is to pack individual soil particles closer together and to crush soil aggregates, thus reducing pore space.
° Resultant additional solid materials per unit volume increase the resistance of the soil to deformation to a point where resistance and stress are in equilibrium and no further compaction occurs.
° As soil-moisture content increases, resistance to stress decreases and compaction can be achieved with progressively reduced loads.
° Maximum density is obtained at a moisture content about midway between field capacity and wilting point.
° Increasing moisture content beyond that point further lowers the resistance to compaction and reduces the maximum density.
° Soils that have the greatest range of particle-size (i.e., medium-textured soils) compact to greatest densities, finer particles filling the voids between coarser particles.
° The less dense the soil, the greater opportunity for compaction.
° The greater the organic content, the smaller the maximum compaction and the greater the moisture content required for maximum compaction.
° Soil freezing tends to compact soil by breaking down water-stable aggregates and tends to loosen compacted soils.
° Duration of compaction depends largely on the stresses the soil undergoes by swelling and shrinking from changes in moisture content and temperatures.
° Compaction increases bulk density, reduces total pore space by the same proportion, reduces noncapillary pore space a greater amount, and has itsgreatest effect on infiltration and percolation.

(Author's summary: partial)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water; physical disturbance of substrate materials; physical trampling or crushing.

Lund, J.A. 1976. Evaluation of stream channelization and mitigation on the fishery resources of the St. Regis River, Montana. USFWS, Washington, D.C. and Cooperative Fishery Research Unit, Montana State Univ., Bozeman. FWS/OBS-76-07. 49 pp. (ADF&G, Habitat Library, #B1983.)

Stream morphology and game fish populations of the St. Regis River, Montana, were studied during the summers of 1973-1975 to determine the effects of stream channelization caused by highway and railroad construction. In-stream structures used to mitigate fish losses also were evaluated. Channel structures produced stream bottom contours similar to those found in unaltered sections. Mitigating structures in altered channels were effective in providing fish habitat comparable to the unaltered sections. Game fish populations in altered sections with mitigation recovered from construction work in about 1 yr. Erosion and turbidity caused during channel construction and the initial unstable channel bottom were of relatively short duration and seemed to have no long-term effects on the biology of downstream areas. New channels usually stabilized after one high-water period. Changes in water temperature and water chemistry due to channel alterations were undetectable. Properly constructed jetties and random rock clusters of large riprap material produced good, economical trout habitat. Fisher-persons favored unaltered or partially altered stream sections, compared to altered sections, probably for aesthetic reasons. Several problems associated with channelization were not alleviated as follows: 1) loss of stream bank vegetation; 2) destruction of natural stream aesthetics; and 3) loss of stream lengths in most cases. The author recommends that original stream channels be altered only when necessary and that such alterations be kept to a minimum. Vegetation along new channels should be retained to provide both bank stability and shade. When riprap is needed to hold the stream in a new channel, it should be covered with subsoil and topsoil down to the high water mark and then revegetated with grass, shrubs, and trees. Jetties, random rock clusters, and other in-stream devices used to create pools must be engineered properly to withstand the annual high water and occasional floods that occur. (Annotation from Stearn and Stearn 1980b)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Lutz, H.J. 1956. Ecological affects of forest fires in the interior of Alaska. USDA, Forest Service Tech. Bull. No. 1133. 120 pp. (ADF&G, Habitat Library, #B5162.)

This report provides a thorough historical background of the incidences of forest fires in interior Alaska. Topics discussed include the effects of fire on forest vegetation, soils, hydrologic processes, annual populations, and economic development. The documentation to support various points made in this report is sometimes scanty and qualitative in nature. It is included here because it specifically pertains to interior Alaska. Forest fires result in a decrease in the relative amount of organic matter in soils, increase the soil temperature, decrease the soil infiltration rates, and increase the surface runoff. Also, soil acidity is reduced, and nutrients bound to organic matter are released. Users are urged to consult this document prior to applying any of the data.

Activity: burning.

Impact: change in depth or velocity of water; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; change in levels of nutrients.

Lyon, L.J., H.S. Crawford, E. Czuhai, R.L. Fredricksen, R.F. Harlow, L.J. Metz, and H.A. Pearson. 1978. Effects of fire on fauna: a state-of-knowledge review. USDA: Forest Service Gen. Tech. Rept. WO-6. (ADF&G, Habitat Library, #B1077.)

This report provides a good review of the effects of fire on terrestrial vertebrate and invertebrate fauna. However, there is very little information relevant to the effects of fire on aquatic biota. The author summarizes his findings (relevant to aquatic habitats) by stating that "the most important effects of fire on stream fauna are related to loss of streamside vegetation and increased sediment land to the stream."

Of the few studies mentioned, most pertain to the loss of streamside vegetation or increase in sedimentation but do not directly involve forest fires. The author apparently uses these studies in this report because of the conceptual linkages between forest fires, damage to habitat, and effects to aquatic ecosystems. A small section of the report is devoted to identifying knowledge gaps and a prioritization of research needs.

Activity: burning.

Impact: change in turbidity or suspended sediments.

MacPhee, C., and F.J. Watts. 1975. Swimming performance of arctic grayling in highway culverts. USFWS, Anchorage, AK. 41 pp. (ADF&G, Habitat Library, #R1149.)

This report presents the results of three seasons of research (1973, 1974, and 1975) in Alaska to test the effect of highway culverts and stream velocity on the swimming performance of arctic grayling (also includes comparative data for long-nosed suckers). Results indicate that upstream spawning migrations are affected by water temperature and the sexual maturity of the fish. Ability to pass the velocity barrier created by a culvert is largely a factor of fish length.

The information presented in this report can be used for the design of moderate-length culverts for fish passage. Appropriate design fish must be selected and the swimming speed of these fish determined. The culvert must be designed so that velocities in the culvert are compatible with fish-swimming capability at the time the fish must move through the culvert. In all circumstances, the tailwater must be maintained at sufficient depth that fish can freely enter the culvert without jumping. This can be accomplished by constructing the invert of the culvert below stream gradeline or by controlling the level of the pool at the outfall of the culvert with some type of sill.

Specific results of the study are as follows: When considering the upstream passage of grayling through culverts, four major variables are involved: the size of fish, the velocity of water within the culvert, the length of the culvert, and the temperature of the water. As the length of culvert and the speed of flow increase, the ability of fish to stem the current decreases. In grayling, to permit 25 to 75% success flows were changed from 6.2 to 5.0 times the fork length of the fish for 18.3-m culverts and from 4.0 to 3.5 times the length for 30.5-m culverts. In the sucker, to permit 25 to 75% success, flows were changed from 4.3 to 3.4 times the fork length of fish for 18.3-m culverts (5-8°C), from 2.6 to 2.3 times the length for 30.5-m culverts (5-8°C), and from 4.2 to 3.2 times the length for 30.5-m culverts (9-12°C). The data indicate that the length of the sucker must be about 1.5 times the length of the grayling to stem the same water velocities.

Activity: stream crossing - structures.

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Malick, J.G., S.L. Schroder, and O.A. Mathisen. 1971. Observations on the ecology of the estuary of Naknek River, Bristol Bay, Alaska. In Univ. Washington, College of Fisheries, Fisheries Research Institute, Salmon Cannery Waste Study. Bristol Bay and Kodiak, Alaska. 1970. 31 pp. (ADF&G, Habitat Library, #B6253.)

In this study, baseline measurement of water quality and abundance of planktonic and benthic invertebrates were conducted, and biotic responses to abundance of the introduction of cannery wastes were assessed on the basis of that information. Up to 715.63 tons of offal from fish processing were discharged each day into the Naknek River and its estuary. However, though the wastes released directly under cannery docks accumulated in large piles during low tide, they were for the most part swept away as the tide came in and went out. Dissolved oxygen concentrations occasionally fell below 7 mg/l at low tide near an operating cannery but were replenished at the next high tide. No build-up of organic matter on the bottom was found in core samples, including samples taken below the dock of an operating cannery. Apparently, the small pieces of flesh released from the canneries after grinding were broken into very fine particles by tidal action and washed out on the ebbing tide, leaving only bone fragments. A comparison between canneries of the rates of consumption of waste tissue by benthic animals was fairly consistent and tends to support two preliminary conclusions: 1) Large pieces of salmon waste, such as heads and tails, were more rapidly consumed in areas away from the canneries (from 14 to 25% per day) than near the canneries (from 0 to 16% per day). Undoubtedly, this difference is due to the large amounts of salmon waste available to benthic animals near the canneries. 2) Larger animals such as fish, crabs, and starfish were primarily responsible for the rapid consumption of soft tissues. It would be desirable to conduct more complete experiments to provide further information on rates of consumption. These observations indicate that the return of a large portion of the discarded animal tissues to the final consumers in the ecosystem surrounding the canneries does not follow the classic pattern of bacterial decomposition of waste into soluble nutrients and their reconstitution into plant and animal tissues. The natural waste disposal system of a cannery bypasses to a large degree this process. Much of the waste is consumed by birds and other fish and is transformed directly into bird and animal tissues. Some of the fish, the Dolly Varden and herring at least, are of recreational and commercial value.

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of nutrients; artificial attractant to biological organisms.

Malins, D.C., ed. 1977. Effects of petroleum on arctic and subarctic environments and organisms. Vol. 2: Biological effects. New York: Academic Press. 500 pp. (ADF&G, Habitat Library, #B0269.)

This volume contains several review papers on the effects of oil, with references to fish and invertebrate species from the North Pacific. Topics addressed in this volume include the following: bioassay techniques for testing acute toxic effects of oil, effects of oil on immune responses and disease resistance of several common fish and invertebrate species; sublethal effects of oil exposure on fish; and a literature review for invertebrates and algae. Several other papers deal with the effects of oil on metabolism, marine ecosystems, arctic environments, marine birds, and marine mammals.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Malins, D.C., and H.O. Hodgins. 1981. Petroleum and marine fishes: a of uptake, disposition and effects. Environ. Sci. and Tech. 15(11):1,272-1,280. (ADF&G, Habitat Library, #R3913.)

Malins and Hodgins provide an excellent review of the effects of oil on marine organisms, emphasizing species from the northeastern Pacific Ocean. Several studies showed that fish exposed to oil in water, sediments, and food supply readily take up hydrocarbons, which accumulate in tissues such as the liver, brain and muscle. How quickly fish can discharge hydrocarbons depends on the species and the tissue where the hydrocarbons are concentrated. Tumors and liver diseases of bottom-dwelling fish such as English sole occur at high frequency in areas with concentrations of hydrocarbons in the sediments.

Sensitivity to oils generally increases from lower invertebrates to fish and is even better correlated with habitat. Pelagic shrimp and fish were the most sensitive of the animals tested; benthic animals, including fish, crabs, and scallops, were moderately tolerant; and intertidal animals, including fish, crabs, starfish, and mollusks were the most tolerant. Anadromous salmon were more sensitive to oil when entering sea water than they were in fresh water. Because eggs and larvae of many flatfish species float near the surface, they are especially susceptible to damage from oil spills.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Malins, D.C., B.B. McCain, D.W. Brown, A.K. Sparks, H.O. Hodgins. 1980. Chemical containments and biological abnormalities in central and southern Puget Sound. Environmental Conservation Div., NWAFC,OMPA-2. 295 pp. (ADF&G, Habitat Library, #B0965.)

Samples of sediments and bottom-dwelling fishes, crabs, shrimps, clams, and worms were collected at quarterly intervals in 1979 from urban and nonurban embayments in Puget Sound. Sediment and tissue samples were analyzed for petroleum hydrocarbons, PCBs, chlorinated pesticides, other chlorinated organic compounds, and metals. Generally, chemical containments associated with the sediments of a location were also present in tissues of biota from that location. The chlorinated hydrocarbons were more abundant in tissue relative to sediment, while the reverse was true for petroleum hydrocarbons. The highest levels of chemical containments in both sediment and biota were found in sites near urban areas; however, containments were also found in the nonurban areas.

Several types of liver lesions were found more frequently in fish from areas with the sediments most highly contaminated by toxic chemcials. The evidence supports the hypothesis that the hepatic lesions found were caused or enhanced by exposure of fish to one or more toxic chemicals found in their environment. In shrimp and crab species, the highest frequencies of abnormalities were found in the hepatopancreas, gill, and bladder tissues. Several of these abnormalities were found only or were most prevalent in the polluted areas.

Activity: processing oil/gas; sewage disposal.

Impact: change in levels of heavy metals; change in levels of chlorinated compounds; change in levels of other toxic compounds - other; change in levels of hydrocarbons.

Malins, D.C., S.L. Chan, H.O. Hodgins, U. Varanasi, B.B. McCain, D.D. Weber, and D.W. Brown. 1981. Sublethal effects of petroleum hydrocarbons and trace metals, including bio-transformations as reflected by morphological, chemical, physiological, pathological, and behavioral indices. Pages 79-171 in Environmental assessment of the Alaskan continental shelf. Annual repts. Vol. 4: Effects of contaminants. 677 pp. (ADF&G, Habitat Library, #R3873.)

The overall objective of this laboratory study was to assess the potential effects of petroleum and petroleum-related operations on marine organisms indigenous to Alaskan waters. The principal objectives were as follows:

1) To complete analyses of previously collected data and provide information concerning effects of petroleum on embryo and larval development of chum salmon (Oncorhynchus keta), flatfish (Pleuronectidae), and surf smelt (Hypomesus pretiosus), and the ability of the organisms to survive in a petroleum-contaminated environment

2) To complete analysis of the effects of exposure to petroleum-impacted sediments on disease resistance of flatfish

3) To assess the effects of petroleum on predator-prey relationships in salmon

4a) To continue studies on the uptake of specific aromatic hydrocarbons (3-, 4-, and 5-ring) in an Alaskan species of flatfish exposed to these compounds in the sediment or by way of their diet

4b) To evaluate the potential of specific petroleum hydrocarbons and their oxidized products for interacting with critical cellular constituents of a key Alaskan species of flatfish

5) To determine the relative toxicities of weathered petroleum components in relation to fresh petroleum hydrocarbons

The conclusions of this study are as follows:

Behavior. Exposure of chum salmon fry to the seawater-accommodated fraction (SWAF) of Cook Inlet crude oil (CICO) at an average concentration of 350 ug/l total hydrocarbons for periods of 24, 48, 72, and 96 h resulted in statistically significant differences (greater at 24, 48, and 72 h and less at 96 h) in consumption rates of the oil-exposed prey by chum predators compared to the consumption of non-oil-exposed controls. Similarly, exposure of coho salmon (O. kisutch) predators to the SWAF of CICO for 10 and 17 d at an average of 343 ug/l total hydrocarbons was correlated with statistically significant alteration (reduction) in the numbers of salmonid fry prey eaten by the oil-exposed predators, compared to the numbers of prey eaten by non-oil-exposed controls. For these experiments, chemical analysis suggested that it was not the parent petroleum hydrocarbons that were primarily affecting the coho's predatory behavior but rather metabolites of the hydrocarbons.

Chemistry. The results show that English sole (*Parophrys vetulus*) exposed to benzo[a]pyrene (B[a]P) in oil-contaminated sediment take up and readily metabolize the hydrocarbon. A number of mutagenic and carcinogenic metabolites were identified in the liver; some of the toxic compounds were bound to cellular macromolecules (e.g., DNA and protein). Further, B[a]P tends to remain largely unconverted in sediment and thus can be available for continued uptake by benthic organisms. Continued uptake, greater retention, and more extensive metabolism of B[a]P than naphthalene (NPH) by benthic fish indicate that, although B[a]P is a minor component of petroleum, its derivatives can be bioconcentrated in tissues of demersal organisms. The substantial bioconversion of B[a]P in fish liver very probably explains why B[a]P is usually not detected in fish tissues even when considerable concentrations of B[a]P are detected in the environment of the fish.

Pathology. Juvenile English sole exposed to CICO-impacted sediments for up to 7 d, and juvenile starry flounder (*Platichthys stellatus*) exposed to Prudhoe Bay crude oil (PBCO)-impacted sediment for up to 6 wk showed no changes in disease resistance as measured by laboratory challenge with the pathogenic bacterium *Vibrio anguillarum*. Also, adult rock sole (*Lepidopsetta bilineata*) exposed to PBCO-impacted sediments for 2 wk did not show an altered ability to resist bacterial infection.

Physiology. Exposure of embryos and larvae of chum salmon, English sole, sand sole (*Psettichthys melanostictus*), and surf smelt to the SWAF of weathered crude oil at concentrations of 100 to 500 ppb typically induced in all species either highembryo mortaility or larval mortality, gross abnormalities, and pathological changes. Exposure of smelt embryos to hydrocarbon concentrations less than 100 ppb resulted in cellular damage to retinal and neural tissue and severely reduced larval survival. Laboratory conditions under which the experiments were conducted were designed to simulate natural conditons in which embryogenesis occurs; thus, it is predicted that the ability of embryos and larvae studied to survive similar oil exposure in the natural environment is similar to that observed.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Martens, D.W., and J.A. Servizi. 1975. Dechlorination of municipal sewage using sulfur dioxide. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 32. New Westminster, B.C., Canada. 24 pp. (ADF&G, Habitat Library, #B6191.)

Simultaneous continuous flow bioassays of primary treated, chlorinated and dechlorinated municipal sewage were conducted with sockeye and pink salmon to evaluate the effectiveness of sulfur dioxide on removal of chlorine and chlorine induced toxicity.

Chlorination decreased the average Mean Survival Time (MST) of sockeye in undiluted primary treated sewage from 293 to 32 min. Dechlorination increased the averge MST to 434 min, indicating that all the chlorine induced toxicity and some primary sewage toxicity was removed. However, sewage that had received primary treatment remained acutely toxic to sockeye and pink salmon following chlorination-dechlorination.

Dissolved oxygen and pH were not adversely affected by sulfur dioxide. The cost of dechlorination using sulfur dioxide is discussed. Lagooning is recommended as an alternative to chemical dechlorination where flows are small and land requirements not great. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Martens, D.W., R.W. Gordon, and J.A. Servizi. 1980. Toxicity of butoxyethyl ester of 2,4-D to selected salmon and trout. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 40. New Westminster, B.C., Canada. 18 pp. (ADF&G, Habitat Library, #B6184.)

Sockeye, coho, and pink salmon and rainbow trout were exposed to butoxyethyl ester of 2,4-D (BEE) derived from the herbicide Aqua-Kleen 20 in semistatic acute and chronic bioassays. The 96-h LC50 was approximately 0.45 mg/l BEE for sockeye fingerlings, coho fry, and pink fry. Rainbow trout were slightly more senstive to BEE than the salmon tested. Sockeye smolts and pink salmon fry survived transfer to sea water after 24-h exposure to concentrations of BEE nearly equal to the 96-h LC50.

Pink and coho salmon and rainbow trout were shorter than control specimens at yolk absorption following exposure to 0.220 mg/l BEE during the alevin stage. No mortality or distress was observed among sockeye fingerlings exposed to 200 mg/l 2,4-D acid for 168 h. The influences of bacterial activity, temperature, and pH on hydrolysis of BEE to 2,4-D acid are discussed. (Author's abstract)

Activity: chemical application.

Impact: change in levels of biocides.

Martin, M.G. 1983. Sources of variability in trace metal bioaccumulation by fish. M.S. Thesis, Fisheries and Wildlife Science, Virginia Polytechnic Institute and State Univ., Blacksburg, VA. 130 pp. (ADF&G, Habitat Library, #B1803.)

Bluegill and channel catfish were collected in 1982 from a metal-contaminated creek in Virginia. Whole-body and tissue concentrations of cadmium, lead, and zinc were determined by atomic absorption spectrophotometry. Variations in metal concentrations within each species were related to the duration of exposure of the fish (i.e., age). Whole-body metal concentrations showed consistent relationships with age in both species: lead concentrations were positively correlated and zinc levels were negatively correlated with age. Cadmium and lead concentrations in liver, kidney, and bone tissues showed variable relationships with age; zinc concentrations generally showed negative correlations with age in tissues of both species.

Habitat differences among species influenced metal accumulation; sediment-dependent species usually showed higher metal concentrations. Organisms from higher tropic levels usually showed low metal concentrations. Differences among species in physiological mechanisms of metal uptake and excretion appeared to be major sources of variation in metal accumulation. Results suggest that older specimens of benthic detrivorous fishes should be used in surveys of metal pollution to accurately express the degree of cumulative contamination in aquatic ecosystems. (Author's abstract)

Activity: dredging; grading/plowing; processing minerals; solid waste disposal; transport personnel/equipment/material - land.

Impact: change in levels of heavy metals.

Martin, C.W., and Pierce, R.S. 1980. Clearcutting patterns affect nitrate and calcium in streams of New Hampshire. J. For. May 1980. 268-272. (ADF&G, Habitat Library, #R2647.)

Streams draining seven forested watersheds in the White Mountains of New Hampshire had average annual nitrate and calcium ion concentrations of about 1.8 mg/l between 1971 and 1973. Nitrate concentrations in streams from nine watersheds that had been clear-cut (all stems larger than 5 cm cut) rose to maximums of 25.1 mg/l. In all streams, the maximum occurred during the second year after cutting. Calcium concentrations rose to maximums of 6.5 mg/l during either the first or second year after cutting. Both nutrients generally returned to reference levels within 5 yr after clear-cutting. Streams draining seven partially clear-cut watersheds exhibited a wide range of nitrate and calcium concentrations. Clear-cutting less than entire watersheds and leaving buffer strips along the streams reduced the magnitude and duration of increases in concentrations. Progressive strip cutting with a buffer strip caused the least increase. (Author's abstract modified)

Activity: clearing and tree harvest.

Impact: alteration of natural cover - riparian vegetation; change in levels of nutrients.

Martin, S.B., and W.S. Platts. 1981. Influence of forest and rangeland management on anadromous fish habitat in western North America, No. 8 - Effects of mining. USDA: Forest Service Gen. Tech. Rept. PNW-119. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 15 pp. (ADF&G, Habitat Library, #R2927.)

This review paper addresses the effects of mining (including surface, auger, quarry or open pit, dredge, hydraulic, and underground or hardrock methods) on anadromous fish habitat. Topics of discussion include sediment production, changes in pH, toxicity of heavy metals, and stream channel and streamflow alteration resulting from mining activities.

The effects of suspended sediment on the aquatic system are direct. Photosynthesis may be reduced because light penetration is reduced; fish migration may be affected; fish may not be able to feed under turbid conditions; suspended solids may interfere with respiration of gilled animals; and turbid waters may cause gill irritation to young salmonids and expose them to infection by fungi and bacteria.

Potential damages to aquatic biota from acid pollution include the elimination of sensitive species and proliferation of tolerant species; reduction in density, biomass, and diversity of aquatic organism; increase in abnormal behavior; and reduction in reproductive capacity of adult salmonids and a reduction in the viability of eggs and alevins.

Heavy metals are commonly found in streams polluted by mine drainage and are toxic to the aquatic biota. Toxicity depends on the fish species, age, stage of development, and numerous other parameters.

The stripping of vegetation and dredging and channelization of streams can occur during mining operations. Such activities can result in increased erosion and sediment because of unstable streamflows. Overall, the effect of mining pollution on the aquatic environment is significant. Where no reclamation efforts are made, the effects of mining on streams may be prolonged long after active mining operations cease.

Activity: processing minerals.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; change in levels of pH, alkalinity, or hardness; change in levels of heavy metals.

Marzolf, G.R. 1978. The potential effects of clearing and snagging on stream ecosystems. USDI: USFWS. FWS/OBS-78/14. 31 pp. (ADF&G, Habitat Library, #B1995.)

This document is included in this volume as an exception to the rule of only including documented impacts. It is included because it brings to light some questions that remain unanswered. Subsequent to this report, one study has substantiated several of the "potential" impacts introduced here (see Benke et al. 1979).

Clearing and snagging, the removal of obstructions from streams to increase the channel's capacity to convey water, is conducted to drain floodplains for agriculture, to protect citizens from floods, or to maintain navigable waterways.

This review examines the widely held contention that such stream alteration reduces fish populations and is otherwise detrimental to the use of stream ecosystems. It was prepared for use in assessing the ecological impact of clearing and snagging projects. Because of the lack of direct quantitative evidence about clearing and snagging effects, the mechanisms involved in producing the effects are discussed indirectly as potential effects.

Recent concepts of stream ecosystem function relate the functions of different groups of stream organisms to organic matter synthesis and degradation in various sizes and types of streams. This review emphasizes the roles obstructions (typically removed by clearing and snagging) exert on these stream ecosystem functions. Recent literature allows one to identify potential effects of clearing and snagging on stream function. Some effects are obvious when viewed in this process-oriented context, while others are less clear. For example, an obvious potential effect of clearing and snagging would be to decrease the rate at which organic matter loads are degraded by the stream system. A less obvious potential effect would be the effects of clearing and snagging on the plankton in streams. The depression of fish populations by clearing and snagging potentially occurs in two ways: 1) through alteration of the nature and abundance of the organisms utilized by fishes as food and 2) by direct effects on fish behavior (territoriality) and reproduction (spawning areas).

This review identifies some potential ecological impacts of clearing and snagging but does not yield quantitative predictions of the impacts. Pertinent recent literature on stream ecosystem function is reviewed and has much application in impact assessment. Parameters that could be measured for quantitatively evaluating the ecological effects of specific clearing and snagging products are described. (Author's abstract)

Activity: channelizing waterways.

Impact: physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation.

Mathers, J.S., N.O. West, and B. Burns. 1981. Aquatic and wildlife resources of seven Yukon streams subject to placer mining. Government of Canada, Departments of Fisheries and Oceans, Indian and Northern Affairs, and Environment, 183 pp. (ADF&G, Habitat Library, #B2706.)

Aquatic resources of Yukon streams subject to placer mining were surveyed in March, May, July and September 1980. Seven streams in the southcentral Yukon Territory, ranging from small tributary creeks to major rivers, were examined. Placer mining activity observed in the study area included sluicing, dredging, and hydraulic mining. Data on water quality, benthic invertebrates, and fish distribution, relative abundance, vital statistics, and food habits were collected for each stream.

Suspended sediment concentrations in areas not disturbed by placer mining ranged from less than 5 mg/l to 100 mg/l, depending on stream discharge. Downstream of most placer mines, suspended sediment levels were between 1,000 and 4,000 mg/l during sluicing. In general, numbers of benthic invertebrates were lower below placer mines, compared to other similar areas. Arctic grayling (Thymallus arcticus) were found in all streams studied; however, spawning and rearing were apparently limited in streams with high sediment loads. Dipterans, trichopterans, ephemeropterans, and plecopterans were most common in grayling stomach samples. Age, growth, and sex ratios of grayling were similar to other northern populations. (Author's abstract, modified)

Activity: dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments.

Maurer, D., W. Leathem, and C. Menzie. 1981. The impact of drilling fluid and well cuttings on polychaete feeding guilds from the U.S. northeastern continental shelf. Mar. Pollut. Bull. 12:342-347. (ADF&G, Habitat Library, #R3912.)

The effect of recent drilling operations on polychaete feeding guilds from the continental shelf off Atlantic City, New Jersey, was examined. Although there were some adverse effects on macrobenthos from 2,160 metric tons of cuttings and mud solids discharged into the marine environment, the composition of polychaete feeding guilds remained essentially unchanged. The increased clay may have affected the abundance of macrobenthos by diminishing recruitment of larvae and burying shallow-dwelling infauna. A significant shift in polychaete feeding guilds might be a precursor to significant disruption in community structure and function.

Activity: drilling.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials.

May, B.E., and B. Davis. 1981. Practices for livestock grazing and aquatic habitat protection on Western rangelands. Pages 271-278 in J.M. Peek and P.D. Dalke, eds. Wildlife - livestock relationships symposium: proceedings 10. 1982. Univ. Idaho, Forest Wildlife and Range Experiment Station, Moscow. 614 pp. (ADF&G, Habitat Library, #R3914.)

From a review of literature, experience, and consultation with others, this report identifies practices that make livestock grazing and protection, preservation, and enhancement of fish habitats more compatible. Grazing activities within rangeland watersheds affect water yield, peak stream discharge and overland storm flows. Primary causes are soil compaction, reduction on infiltration rates, and vegetation reduction. Rangeland grazing also changes streamside vegetation, channel and bank morphology, and water quality. Fish populations have been altered by riparian zone grazing. Unstable stream conditions can be aggravated by intense grazing.

Stream size and physical characteristics closely relate to intensity of grazing. Streams most susceptible to overgrazing are those with low channel gradients, bank rock materials composed primarily of smaller gravels, bank vegetation dominated by grasses, sedges, and forbs, and woody species are present in small numbers. These stream features correlate with the zones of high fish production and cover.

Activity: grazing.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - overhanging bank or shoreline.

McCabe, G.D., and W.J. O'Brien. 1983. The effects of suspended silt on feeding and reproduction of Daphnia pulex. Am. Midl. Nat. 110(2): 324-337. (ADF&G, Habitat Library, #R2714.)

This paper reports the effect of suspended silt on the feeding and reproduction of Daphnia pulex and the impact of suspended silt and clay on the freshwater zooplankton community structure. The effects of suspended silt and clay on the filtering and assimilation rates of Daphnia pulex were determined using the ^{14}C radiotracer method. Both filtering and assimilation rates are severely depressed at even low concentrations of suspended silt and clay. Life table studies also showed that the population growth rate of zooplankton was significantly diminished by suspended silts and clays. The relative abundance of zooplankton varied markedly between two lakes of differing turbidity levels, the more turbid lake having a higher relative abundance of large zooplankton species. Suspended silt and clay reduced zooplankton feeding and production but probably influenced the zooplankton community structure by impairing the ability of visually feeding planktivorous fish to locate prey. (Author's abstract)

Activity: clearing and tree harvest; dredging; grading/plowing.

Impact: change in turbidity or suspended sediments.

McCashion, J.D., and R.M. Rice. 1983. Erosion on logging roads in northwestern California: how much is avoidable? J. For. 81(1):23-26. (ADF&G, Habitat Library, #R3854.)

This study was conducted on 344 mi of logging roads in northwestern California to assess sources of erosion and the extent to which road-related erosion is avoidable. At most, approximately 24% of the erosion measured on the logging roads could have been prevented by conventional engineering methods. The remaining 76% was caused by site conditions and choice of alignment. On 30,300 acres of commercial timberland, an estimated 40% of the total erosion associated with management of the area was found to have been derived from the road system. (Author's abstract: modified)

Activity: grading/plowing.

Impact: addition of substrate materials; physical disturbance of substrate materials.

McCrimmon, H., and W.H. Kwain. 1966. Use of overhead cover by rainbow trout exposed to a series of light intensities. J. Fish. Res. Bd. Can. 23(7):983-990. (ADF&G, Habitat Library, #R5103.)

Observations made on fingerlings and yearling trout (Salmo gardneri Richardson) exposed to the series of artificial daylight illuminations showed differences in the response of each to the overhead cover at all of the test light intensities, except that of total darkness. It was found that the fingerling trout showed no preference for either the covered or open areas of the tank, being randomly distributed at all of the test light intensities. The yearling trout, however, demonstrated a significant preference for the covered portion of the tank under all test light intensities except when randomly distributed in total darkness. The reaction of the yearling trout varied with the light intensity when first put in the tank, the movement to beneath the cover being more immediate at the higher rather than the lower light intensity. Also, their subsequent movement between the covered and open areas of the tank was more pronounced at the higher light intensities. These observed differences in response to light with age are in agreement with the results of several workers concerned with other aspects of fish behavior and physiology. (Author's discussion: partial)

Activity: channelizing waterways.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

McDaniel, N.G. 1973. A survey of the benthic macroninvertebrate fauna and solid pollutants in Howe Sound. Fish. Res. Bd. Can. Tech. Rept. No. 385. 64 pp. (ADF&G, Habitat Library, #B0086.)

Solid pollutants resulting from industrial activities, such as log-booming and mining, cause a marked reduction in the ability of the substrate to support colonization by benthic organisms. Where input of solid wastes is intense or of long duration, establishment of benthic fauna is sometimes entirely precluded. Long-term log storage and dumping activities in Howe Sound have resulted in massive, although localized, accumulations of sunken logs and wood debris that blanket the natural substrate and support only a few species of invertebrates. Long-term mining operations at Britannia have resulted in the buildup of a thick layer of tailings on the bottom adjacent to the mine that have not been colonized by benthic organisms. Commercial marina operations have resulted in the accumulation of inorganic refuse on the bottom, which in some instances provides artificail hard substrate for the attachment of epifauna or crevice space for motile forms but which is more often aesthetically unpleasant.

Activity: log storage/transport; solid waste disposal.

Impact: addition of substrate materials.

McDaniel, N.G., R.D. MacDonald, J.J. Dobrocky and C.D. Levings. 1976. Biological surveys using in-water photography at three ocean disposal sites in the Strait of Georgia, British Columbia. Fish. Mar. Serv. Res. Dev. Tech. Rept. 713: 47 pp. (ADF&G, Habitat Library, #B6263.)

As part of Environment Canada's Ocean Dumping field work program, remote in-water still photography was one of several techniques employed to determine the nature of the substrate and associated benthos at selected ocean dumping grounds in the vicinity of Vancouver, British Columbia. Camera operations were carried out at dumpsites in the Strait of Georgia off Point Grey, in Thornbrough Channel near Port Mellon, and in Vancouver Harbour.

Photographs at the Point Grey dumpsite depicted a generally flat, silt/clay substrate with accumulations of dumped materials at stations to the northeast of the center of the dumpsite. The most abundant epibenthic macrofauna was the ophiuroid. At Port Mellon the photographs indicated a substrate disturbed by large accumulations of wood waste widely distributed in front of the mill. A crab species was the most common macrobenthic organism encountered. In Vancouver Harbour, most of the bottom photographs depicted a silt-sand substrate generally lacking in macrobenthos. (Author's abstract: modified)

Activity: solid waste disposal.

Impact: addition of substrate materials.

McGreer, E.R., D.M. Moore, and J.R. Sibert. 1984. Study of the recovery of intertidal benthos after removal of log booms, Nanaimo River estuary, British Columbia. Can. Tech. Rept. Fish. Aquat. Sci. 1246. (ADF&G, Habitat Library, #B6108.)

Intertidal benthic communities in the Nanaimo River estuary were monitored to assess their recovery from the impacts of log boom storage. Changes at a site from that log booms were removed were compared to those at an adjacent reference site which had not been used for log storage. Species composition of meiofauna (harpacticoid copepods) and macrofauna (amphipods, molluscs, annelid worms) at the log removal site remained substantially different from that at the reference site 13 mo after log removal. Harpacticoids were frequently found in greater numbers at the log removal site while macrofauna species were reduced in number compared to the reference site. One species of amphipod, Corophium insidiosum, occurred in high numbers only at the log removal site and was suggested as a possible indicator species for future studies. Other species occurring at the log removal site were common indicators of organic enrichment in marine sediments.

Measurement of sediment physical/chemical characteristics showed no consistent differences between the two test sites for sediment particle size, total organic carbon, and total Kjeldahl nitrogen. The most significant feature of the log removal site was the persistence of a shallow reducing layer, which resulted in anoxia and production of hydrogen sulfide. The anoxic sediments were considered to be a major factor affecting benthic communities at the log removal site. Implications of the findings with respect to estuarine fisheries are discussed. (Author's abstract)

Activity: log storage/transport.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

McIntyre, A.D. 1979. Effects of pollution on inshore benthos. Pages 301-318 in B.C. Coull, ed. Ecology of marine benthos. Columbia Univ., S. Carolina, Bell W. Baruch Lib. Mar. Sci. (6). 467 pp. (ADF&G, Habitat Library, #R3921.)

McIntyre designed a program of long-term laboratory experiments, biological assays, and field observations to assess the effects of pollution on benthos of the coastal region in Scotland. The experiments, using a three-level food chain represented by phytoplankton, a benthic bivalve (Tellina tenuis), and a juvenile flatfish (Pleuronectes platessa), indicated that low levels of pollutants, sometimes two orders of magnitude less than the LC50 value, can have significant adverse effects at each of the three trophic levels. High BOD and nitrate levels were identified as indicators of unfavorable water conditions.

Results from some of the copper and mercury experiments indiated that copper, added as aqueous copper sulphate, had significant effects at all concentrations (10, 30, and 100 ug Cu/l) on all levels of the food chain: reduction in phytoplankton activity, decline in bivalve condition, and decrease in fish growth. Mercury concentrations of 0.1, 1.0, and 10 ug Hg/l, added as aqueous mercuric chloride, showed similar but less marked effects. In the tanks enriched with nitrogen (3.0 ug at NO3-N/l) and phosphorus (0.6 ug at PO4-P/l), no significant modification was observed in the copper or mercury effects. When copper and mercury at the intermediate dose levels were applied together, no synergistic effects were observed.

Extension of these laboratory studies to benthic communities in the field showed a quantitatively enhanced macrofauna inhabiting a polluted coastal area, but there were signs that the associated microfauna were under stress. The adverse effects resulted from such factors as the accumulation of fine particulate material and the toxic reactions of metals and other contaminants. McIntyre noted that it is usually impossible to identify one factor as the cause of pollution. Even if adult organisms are resistant to pollution, planktonic larvae could be affected, leading to reduction of recruitment.

Activity: processing minerals; sewage disposal.

Impact: change in levels of heavy metals; change in levels of nutrients.

McIntyre, A.D., and R. Johnston. 1975. Effects of nutrient enrichment from sewage in the sea. Pages 131-141 in A.L.H. Gameson, ed. Discharge of sewage from sea outfalls. Supplement to progress in water technology. Pergammon Press. 455 pp. (ADF&G, Habitat Library, #R3901.)

The major effects from sludge-dumping and sea outfalls tend to be on the bottom and on sites where water movement is slight. On these sites, the diversity of the benthos is reduced. The effects of nitrogen and phosphorus addition normally operate through the primary producers, phytoplankton and macroalgae, and secondary effects on the environment and the food chain may follow.

On a site where the diversity of the benthos is reduced, the most important effect may be the loss of a fishing ground to the bottom fishery. Fish do not seem to prey on the invertebrate benthos that dominates the high organic areas at the entrance of dumping grounds, the effect may be enhancement of the bottom community rather than species reduction, and fish do actively feed in these areas. The most significant change for fisheries can be expected from loss of bottom-dwelling fish that live in the deposit, rather than from pelagic species.

Activity: sewage disposal.

Impact: change in level of dissolved oxygen, nitrogen; change in levels of nutrients; introduction or removal of species.

McKeown, B.A. 1981. Long-term sublethal and short-term high dose effects of physically and chemically dispersed oil on accumulation and clearance from various tissues of juvenile coho salmon, Onchorhynchus kisutch. Mar. Environ. Res. 5:295-300. (ADF&G, Habitat Library, #R3892.)

The toxicity of crude oil and the dispersant BP1100X was tested in sea water and in each case was much less than the toxicity to fish in fresh water. Uptake of oil from water, with or without dispersant, was similar after a short exposure to 200 ppm. The oil was cleared from the fish in 3 wk. A long-term exposure to oil or oil plus dispersant at a concentration of 5 ppm showed a slow accumulation but significantly above exposure levels. Thus, salmon exposed to oil in sea water can take up the hydrocarbons but appear to cleanse themselves rapidly.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

McLeay, D.J., C.C. Walden, and J.R. Munro. 1979. Effect of pH on toxicity of kraft pulp and paper mill effluent to salmonid fish in fresh and seawater. Water Res. 13:249-254. (ADF&G, Habitat Library, #R5141.)

In freshwater bioassays with juvenile rainbow trout (Salmo gairdneri), at initial pH values from 4 to 11, kraft mill effluents were considerably less toxic at pH 9-10 than at neutrality. When pH of test solutions was controlled throughout the bioassay period, the least toxic range was 8.5-9.5. Toxicity at typical receiving water pH values was 50-67% greater.

The acute toxicity of effluent samples to yearling coho salmon (Oncorhynchus kisutch) was identical for these effluents in sea water and fresh water, respectively, provided that the pH was adjusted and held at the same value and that test fish were previously acclimated to the dilution water for several months. Thus seawater constituents other than pH did not affect the acute toxicity of pulp and paper mill effluents appreciably. (Authors abstract)

Activity: processing lumber/kraft/pulp.

Impact: change in levels of pH, alkalinity, or hardness; change in levels of other toxic compounds - other.

McLeay, D.J., A.J. Knox, J.G. Malick, I.K. Birtwell, G. Hartman, and G.L. Ennis. 1983. Effects on arctic grayling (Thymallus arcticus) of short-term exposure to Yukon Placer Mining Sediments: laboratory and field studies. Dept. Fisheries and Oceans, West Vancouver, B.C. Can. Tech. Rept. Fish. Aquat. Sci. No. 1,171. 134 pp. (ADF&G, Habitat Library, #B4471.)

This paper presents the results of work undertaken to study the short-term tolerance of juvenile arctic grayling to placer mining sediment under both laboratory and field conditions and to determine nonlethal effects of short-term exposures to suspended sediments of different types (inorganic fines "paydirt" and organic soil "overburden").

Wild grayling were acclimated to warm (15°C) or cold (5°C) water conditions for 7-12 wk and subjected to a range of sediment concentrations. Grayling fingerlings were also held for 4 or 5 d in cages downstream of placer mining activities on Highet Creek and in the clear waters of Minto Creek (upstream of Highet Creek). Differences in blood sugar values indicated that grayling caged in Highet Creek experienced greater physical stress than those held in Minto Creek.

Laboratory bioassays demonstrate that underyearling arctic grayling can survive short-term exposure to very high levels (greater than or equal to 50,000 mg/l) of suspended inorganic or organic sediment. Season does not cause any marked changes in this tolerance, although test results suggest a slight reduction in lethal tolerance to suspensions of inorganic paydirt for grayling acclimated to cold water. These laboratory findings are consistent with the fish-survival data obtained for grayling held in turbid waters downstream of placer mining activity for 4 or 5 d.

Results indicate that suspended sediment strengths as low as 50 mg/l (overburden) may be stressful to underyearling arctic grayling and that stress responses can be evoked for both cold-water and warm-water-acclimated fish.

Activity: dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials.

McLeay, D.J., G.L. Ennis, I.K. Birtwell, and G.F. Hartman. 1984. Effects on arctic grayling (<u>Thymallus arcticus</u>) of prolonged exposure to Yukon placer mining sediment: a laboratory study. Can. Tech. Rept. Fish. Aquat. Sci. 1241. 96 pp. (ADF&G, Habitat Library, #B5055.)

The effects on underyearling arctic grayling of a 6-wk exposure to differing strengths of suspended placer mining sediment was examined under controlled laboratory conditions. Groups of 60 grayling were placed into eight test streams and acclimated to laboratory feed and water quality conditions. Thereafter, sediment collected from the downstream end of a Yukon placer mine settling pond was introduced continuously to six streams at a controlled rate of 100, 300, or 1,000 mg/l (two streams per treatment). Two control streams continued to receive clear freshwater.

The survival of fish in each stream throughout the 6-week test period was high (87-95%) and unaffected by the sediment suspensions. Fish growth, as monitored by weekly weighings of individual fish, was significantly decreased (relative to control fish) by sediment concentrations of 100 and 300 mg/l, and more markedly impaired (33% relative to controls) by 1,000 mg/l. The linear distribution of grayling in each stream was unaffected by the lowest (100 mg/l) suspended sediment concentration examined; however, the majority of fish held in each stream containing 300 or 1,000 mg/l sediment were displaced downstream throughout the test period.

All suspended sediment strengths examined increased the response times to detect and consume surface drift relative to those for control fish.

It was concluded that, whereas chronic exposure of arctic grayling to suspended sediment concentrations less than or equal to 1,000 mg/l may not cause direct mortalities of fish or impair their respiratory activity, suspended sediment strengths above 100 mg/l causes a number of sublethal effects including impaired feeding ability, reduced growth rates, downstream displacement, decreased scope for activity, and decreased resistance to other environmental stressors. (Author's abstract: modified)

Activity: dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments.

McMahon, J., J. Wolf, and M. Diggins. 1972. Chironamidae, Ephemeroptera and Trichoptera in the benthos of unchannelized and channelized portions of the Missouri River. Proc. South Dakota Acad. Sci. 51:168-181. (ADF&G, Habitat Library, #R5121.)

Of the three taxa identified in the title of this paper, only the Chironomidae were quantitatively evaluated. Only qualatative data are provided for the other two taxa. Sampling sites included stations in both Iowa and South Dakota. Chironomids comprised 52 to 80% of the total number of benthic organisms in channelized sections and 64 to 90% of the organisms found in the unchannelized sections. Habitat diversity was greatest in the unchannelized river habitat having five distinguishable habitat types (main channel, sand shore, sand bar, mud shore, and cattails). Of these, only two were represented (mud shore, main channel) in channelized river sections. For these two habitat types, the density of organisms in unchannelized main channel habitats were 4.5 times greater and nearly the same in mud shore habitat compared to channelized river areas. Of all five habitat types, cattail habitat contained approximately twice the density of chironamids per sq meter. A total of 27 genera of Chironamidae were found, 23 in the unchannelized areas and 20 in the channelized river areas.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; introduction or removal of species.

McMaster, K.M., R.G White, R.R. Ringe, and T.C. Bjornn. 1977. Effects of reduced nightime flows on upstream migration of adult chinook salmon and steelhead trout in the lower Snake River. Project completion report to U.S.A.C.E., Walla Walla District. Contribution No. 93 to Forest, Wildlife, and Range Experiment Station, Univ. Idaho. 64 pp. (ADF&G, Habitat Library, #B1210.)

Storage of water at night and discharge through turbines at lower Snake River, Idaho, dams during the day would best meet demands for power production. During 1975 and 1976, the effects of reduced nighttime flows on the upstream migration of adult chinook salmon and steelhead trout were assessed. During the summer and fall, reducing discharge from the dams to zero at night (2300 to 0700 h) had no obserable effect on the migration of adult fish.

No differences in behavior or rates of travel were noticed in radio- and magnetically tagged chinook or steelhead which could be attributed to nighttime flow regimes. Few tagged chinook salmon passed through the study area. amd this was attributed to handling stress. Seventy-five percent of all steelhead tagged passed through the study area during flow tests. Total movement and recapture of steelhead tagged and released during late October and early November decreased with the onset of overwintering behavior associated with decreasing water temperature. (Author's abstract: modified)

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water.

McNeil, W.J., and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. USFWS, Spec. Sci. Rept.-Fisheries No. 469. 15 pp. (ADF&G, Habitat Library, #R2872.)

The size composition of bottom materials was studied as part of an investigation of the effects of logging on pink salmon streams in Alaska. Observations were made mostly in streams located near Hollis on Prince of Wales Island.

During this study, one instance was recorded where siltation of spawning beds occurred in association with logging. Flooding removed most of the silt accumulating from logging.

The potential of a salmon spawning bed to produce fry is directly related to its permeability. There was an inverse relationship between the permeability and the fraction of bottom materials consisting of fine particles.

Pronounced differences in the size composition of bottom materials were observed among several pink salmon spawning streams. The more productive spawning streams had the highest permeability.

Activity: clearing and tree harvest.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

McNulty, J.K. 1970. Effects of abatement of domestic sewage pollution on the benthos, volumes of zooplankton, and the following organisms of Biscayne Bay, Florida. Univ. Miami, Institute of Miami and Atmospheric Sciences, Studies in Tropical Oceanography No. 9. 106 pp. (ADF&G, Habitat Library, #B6272.)

Various elements of the biota of northern Biscayne Bay, Florida, were studied before and after abatement of polluation. The pollution consisted of 136 to 227 x 10 l/d of untreated domestic sewage. Four years after removal of the pollution certain changes had taken place. At distances of 100 to 740 m seaward from outfalls, in water depths of 1 to 3 m in hard bottom, populations of benthic macroinvertebrates had declined from abnormally large numbers of species and individuals to normal numbers of each, while soft-bottom populations had changed qualitatively but not quantitatively. Adjacent to outfalls, populations had increased in numbers of species and numbers of individuals in hard sandy bottoms only. Volumes of zooplankton had decreased to about one-half the preabatement values in poorly flushed waters; elsewhere, they remained about the same. Dissolved inorganic phosphate-phosphorus decreased similarly. Abundance of amphipod tubes had declined markedly, a change not shared by the quantities of other fouling organisms (including barnacles), which remained about the same. There was no evidence of improved commercial and sport fishing following abatement; this is interpreted to mean that long-lasting detrimental effects have resulted from pollution and dredging. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of other toxic compounds - other; change in levels of nutrients.

Mecklenburg, T.A., S.D. Rice, and J.F. Karinen. 1977. Molting and survival of king crab (Paralithodes camtschatica) and coonstripe shrimp (Pandalus hypsinotus) larvae exposed to Cook Inlet crude oil water-soluble fraction. Pages 221-228 in D.A. Wolfe, ed., Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems, Proceedings of a-symposium, 10-12 Nov. 1976, Seattle, Wash. New York: Pergamon Press. (ADF&G, Habitat Library, #R1302.)

Larvae of coonstripe shrimp and king crab were exposed to solutions of the water-soluble fraction (WSF) of Cook Inlet crude oil in a series of tests on intermolt Stages I and II and the molt period from Stage I to Stage II. Molting larvae were more sensitive than intermolt larvae to the WSF, and molting coonstripe shrimp were more sensitive than molting king crab larvae. When molting larvae were exposed to high concentrations of the WSF (1.15-1.87 ppm total hydrocarbons) for as little as 6 h, molting success was reduced by 10-30%, and some deaths occurred. When larvae were exposed to these high concentrations for 24 h or longer, molting declined 90-100%, and the larvae usually died. The lowest concentrations tested (0.15-0.55 ppm total hydrocarbons) did not inhibit molting at any length of exposure, but many larvae died after molting. Median lethal concentrations (LC_{50}s) based on 144 h of observation for molting coonstripe shrimp and 120 h for molting king crab were much lower than the 96-h LC_{50}s, showing that the standard 96-h LC_{50} is not always sufficient for determining acute oil toxicity. Although our LC_{50}s for intermolt larvae are higher than levels of petroleum hydrocarbons reported for chronic and spill situations, some of our LC_{50}s for molting larvae exposed 24-h and longer are similar to or below these environmental levels. Comparisons of sensitivity to oil between different crustacean species or life stages should be based on animals tested in the same stage of the molt cycle, such as intermolt. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Mecum, R.D. 1984. Habitat utilization by fishes in the Tanana River near Fairbanks, AK, USA. M.S. Thesis. Univ. Alaska, Fairbanks. (ADF&G, Habitat Library, #B1999.)

This study evaluated summer habitat utilization of fishes and the effects of floodplain developments on fish and aquatic habitat in the glacially fed Tanana River near Fairbanks, Alaska. Aquatic habitats were quantitatively described on the basis of water velocity, depth, and clarity, and substrate, cover, and vegetation. Lake chub and longnose sucker were abundant in all habitats. Whitefishes, juvenile salmon, and northern pike were captured most frequently in areas with high water clarity. Burbot preferred deeper, turbid waters. Young-of-the-year of lake chub and longnose sucker preferred shallow, silty backwaters; juvenile lake chub demonstrated no habitat preferences; and adult lake chub, juvenile longnose sucker, and juvenile/adult slimy sculpin preferred gravel riffles. Bank stabilization activities have significantly modified aquatic habitat and fish communities of Tanana River backwaters. In general, free-flowing side channels have become block-off sloughs resulting in reduced turbidities and lower flows. These changes have resulted in both positive and negative effects on fish and their habitat. Positive changes include increases in water temperature, water level stability, water clarity, and cover. Alterations to backwaters generally resulted in shifts from riverine species to those preferring lake-like habitat. If groundwater flow and surface runoff are adequate, the blockage of upper ends of side channels may be a way to improve fish habitat and mitigate losses in other areas. Otherwise, backwater areas may eventually fill in and become a permanent part of the developed floodplain. Negative changes include losses in total water surface area and potential fish habitat, increased sediment depostion, and increased likelihood of development in blocked sidechannels. (Author's abstract: modified)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; alteration of natural cover - overhanging bank or shoreline.

Meehan, W.R. 1974. Fish habitats. Vol. 3 in W.R. Meehan, ed., The forest ecosystem of Southeast Alaska. Series 1974-1978. USDA: Forest Service. Gen. Tech. Rept. PNW-15. Portland, OR. (ADF&G, Habitat Library, #B3010.)

Consideration for fish habitat in Southeast Alaska during timber harvesting was in the past often directed only toward the larger spawning streams. Today, the great importance of the smaller rearing areas is being more fully recognized, and these areas are now beginning to receive the attention which they warrant. Small streams are generally more dramatically affected by changes than are larger streams and rivers.

Sediment (both suspended and deposited), water temperature, dissolved oxygen, streamflow, and debris are the factors associated with logging practices which can affect the habitat of anadromous and resident fish populations. These factors often are interrelated, and the total cumulative effects may be greater than the sum of their individual effects. For example, if streamside shade is removed from a reach of stream, water temperature will be increased. If logging debris accumulates in this reach, dissolved oxygen levels may be reduced. If sediment is introduced, intragravel water flow and the interchange between surface and subsurface waters may be inhibited. Each of these factors might cause a reduction in salmon egg survival if it was the only factor involved. However, if all three conditions were to occur simultaneously, still greater effects could be produced. Increased water temperature would increase the oxygen demand produced by the decomposing debris, thereby further decreasing the dissolved oxygen content of the water. The sediment would decrease the interchange and flow of water through the gravel, further limiting the amount of oxygen reaching the embryos and also inhibiting removal of waste products produced by the embryos and the decomposing debris. The total effect on the developing eggs of this combination of conditions could be much more disastrous than the sum of their individual influences.

Sediment and fine logging debris (bark, leaves, twigs) are not compatible with high quality fish habitat. There is an inverse relationship between the accumulation of these materials and salmonid production. This consequence must be considered when timber sales are laid out and during logging (e.g., road location, falling, and yarding away from streams).

Water temperature is controlled by the amount of solar energy reaching the stream. Such factors as surface area of stream, amount of streamflow, groundwater, and tributary influences may ameliorate the effects, but shade is of greatest importance. As shade cover is removed, summer water temperatures will rise. Within limits, temperature increases in small streams as a result of removing streamside vegetation can be predicted. In some situations a slight warming of stream water might enhance fish production, but the cumulative downstream effects of temperature increases in upstream tributaries must be considered.

Log jams and large debris may limit fish production in one stream; in another stream this material could be beneficial. Streamflow should increase as a result of clear-cutting. In Southeast Alaska, there is no evidence that this is a major factor in causing increased storm flows. The climate and high infiltration rates of the soil probably account for the inability to observe streamflow increases. (Author's summary:partial)

Activity: chemical application; clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation; change in level of dissolved oxygen, nitrogen; change in levels of biocides.

Meehan, W.R., and D.N. Swanston. 1977. Effects of gravel morphology on fine sediment accumulation and survival of incubating salmon eggs. USDA Forest Service Res. Pap. PNW-220:Portland, Or. 16 pp. (ADF&G, Habitat Library, #B6260.)

The results of this study suggest that in the absence of storm flows, gravel shape can have an appreciable effect on short-term sediment accumulation in spawning gravels. This is particularly evident for flow rates less than 0.8 m^3/s. At very low flows, less than $0.2m^3/s$, round gravels tend to accumulate more fine sediment than angular gravels. This relationship is reversed as flow rates increase above approximately 0.4 m^3/s and angular gravels tend to accumulate more sediment.

Survival of salmonid embryos, at least in the early stages of development, may be somewhat greater in angular gravels than in other gravel types. Because the amount of fine sediment that accumulates during a range of water flow conditions is somewhat greater in angular gravels than in other gravel types, embryo survival may at times be highest in those gravels containing the most fine sediment; this situation is probably due to other factors, such as amount of intragravel void space, water velocity, etc. (Author's abstract: partial)

Activity: clearing and tree harvest; dredging; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials.

Meehan, W.R., M.D. Bryant, P.E. Porter, R.D. Orchard, and T.L. Hickman. 1985. Anadromous fish habitat research program for coastal Alaska. USFS, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Juneau, AK. 53 pp. (ADF&G, Habitat Library, #B2018.)

This annual report briefly describes the purpose, objectives, and status of 14 studies conducted by the Anadromous Fish Habitat Project in Southeast Alaska. Where available, a summary of results is provided. However, in many cases the results may be preliminary and subject to change. The four subject areas addressed in the report included the following:

1) Relationship between intragravel conditions in spawning areas and survival of salmonid embryos

2) Salmonid rearing habitat utilization with respect to winter conditions, beaver dams, and off-channel areas

3) Effects of timber harvest activities on riparian vegetation as it affects anadromous fish habitat

4) Enhancement and rehabilitation of salmonid rearing and spawning habitat.

Activity: clearing and tree harvest.

Impact: addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation.

Meekin, T.K., and R.L. Allen. 1974. Pages 127-153 _in_ Washington Dept. of Fish., comp. Nitrogen supersaturation investigations in the mid-Columbia River. Wash. Dept. of Fish. Tech. Rept. No. 12. 153 pp. (ADF&G, Habitat Library, #R4369.)

Prespawning mortality of adult summer chinook (_Oncorhynchus tshawytscha_) and sockeye (_Oncorhynchus nerka_) salmon was first observed in the upper Columbia River, downstream from Chief Joseph Dam, in 1965. During the same year, the Columbia River was found to be supersaturated with nitrogen gas. Boat searches and aerial reconnaissance flights were conducted from 1965 through 1970 to estimate the extent and cause of the mortality. Samples of Columbia River water were analyzed during the same period to monitor the levels of supersaturated nitrogen gas. The mortalaity was estimated by using a carcass tagging-recovery study in 1967 and a spawning fish per redd factor of 3.1:1 from 1968-1970. The estimated mortalities were 59.3% of the Wells Dam summer chinook escapement in 1967, 44.3% in 1968, 55.6% in 1969, and 5.5% in 1970. Overall sockeye mortality estimates were not made because of less efficient spawning ground survey methods for this species.

The evidence indicated that supersaturated nitrogen is caused by spilling at the Columbia River dams and is associated with significant mortalities of fish life. From 1965 through 1968, considerable numbers of floating salmon carcasses were found in the river. These carcasses coincided in timing with spilling and nitrogen levels in excess of 120%. During 1970, few floater carcasses were found, spilling was reduced from previous years both in time and volume, and fish were not subjected to levels higher than 117%. (Author's abstract)

Activity: water regulation/withdrawal/irrigation.

Impact: change in level of dissolved oxygen, nitrogen.

Meekin, T.K., and B.K. Turner. 1974. Tolerance of salmonid eggs, juveniles, and squawfish to supersaturated nitrogen. Pages 78-126 in Washington Dept. of Fish (Comp.). Nitrogen supersaturation investigations in the mid-Columbia River. Wash. Dept. of Fish. Tech. Rept. No. 12. 153 pp. (ADF&G, Habitat Library, #R4368.)

Bioassays were conducted on several species of salmonid eggs and juveniles and squawfish to investigate their tolerance to varying levels of super-saturated nitrogen. The majority of the tests were conducted in shallow troughs with oxygen saturations of less than 100%. Additional tests were conducted with live cages in the Columbia River.

The results showed that species of juvenile salmonids tested can withstand prolonged exposure to concentrations of 112% dissolved nitrogen gas with few mortalities occurring. Depth was shown to be a compensating factor when nitrogen supersaturation is present. Large juveniles of the species tested will succumb to nitrogen in less exposure time than smaller fish. Bubbles (emboli) are the most common external symptoms of nitrogen gas. Juvenile exposed to the lethal levels and succumbing in short exposure periods did not always show external symptoms. Squawfish can tolerate levels of 120% saturation but will not actively feed at this level.

Further studies are recommended to obtain more precise data on the extent of mortality to naturally migrating juvenile salmonids resulting from nitrogen supersaturation. (Author's abstract)

Activity: water regulation/withdrawal/irrigation.

Impact: change in level of dissolved oxygen, nitrogen.

Megahan, W.F. 1972. Subsurface flow interception by a logging road in mountains of central Idaho. Pages 350-356 in National symposium on watersheds in transition, 1972, Intermountain Forest and Range Experiment Station, Ogden, Utah. (ADF&G, Habitat Library, #R3846.)

The hydrologic impact of roads is usually evaluated on the basis of changes in hydrologic processes (interception, infiltration, etc.). With few exceptions, these changes create increased volumes and rates of runoff compared to preconstruction conditions. However, another dimension is added when roads are constructed in mountains; in such areas, subsurface flows intercepted by roadcuts can be an important consideration.

The relative importance of subsurface flow interception is illustrated by the results of this study, even though direct runoff from the area disturbed by roads was not measured. The interception of subsurface flow is one of the more insidious effects of road construction because its occurrence often is not readily apparent. Subsurface flows occur only during large rains and/or snowmelt when large volumes of water are supplied to the soil. Much of the erosion associated with road construction is very likely a direct result of subsurface flow interception.

Because the study outlined in this report involved a relatively small surface area of two watersheds, conclusions surrounding subsurface flow interception must be tempered with knowledge of characteristics unique to the watersheds studied. The yield per unit of surface area was slightly higher in one watershed; yet a great difference existed in the total amount of area supplying water to each sampling station (2.4 versus 0.8 acres, respectively). Thus, road location and position with respect to the amount of subsurface flow drainage area above the road becomes an important consideration of total impact.

Activity: grading/plowing.

Impact: change in depth or velocity of water.

Megahan, W.F., and W.J. Kidd. 1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. J. For. 70(3): 136-141. (ADF&G, Habitat Library, #R3838.)

Erosion plots and sediment dams were used to evaluate the effects of jammer and skyline logging systems on erosion and sedimentation in steep, ephemeral drainages in the Idaho Batholith of central Idaho. Five-year plot data indicated that no difference in erosion resulted from the two skidding systems as applied in the study. Sediment dam data obtained concurrently showed that the logging operations alone (excluding roads) increased sediment production by a factor of about 0.6 over the natural sedimentation rate. Roads associated with the jammer logging system increased sediment production an average of about 750 times over the natural rate for the 6-yr period following construction. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials.

Megahan, W.F., and D.C. Molitor. 1975. Erosional effects of wildfire and logging in Idaho. Pages 423-444 in Proceedings of watershed management symposium, Logan, Utah, Aug. 11-13, 1975. (ADF&G, Habitat Library, #R3924.)

This study was conducted following a wild fire that burned an area being studied for subsurface flow differences between logged and unlogged watersheds (see Megahan 1972). Drainage areas for the clear-cut and uncut watersheds were 2.4 and 0.8 acres, and are representative of first order drainages found in mid-elevation, fluvial landscapes of the Idaho Batholith.

Considerable accelerated erosion (both rill and splash erosion) occurred on the clear-cut watershed. A conservative estimate of the amount of sediment outflow from the clear-cut watershed for the first 11 mo after burning is 1.12 m^3 based upon collection trough and erosion pin data. This amounts to an annual sediment yield of 127 m^3/km^2 per year. Slight splash erosion was recorded on the uncut watershed, but there was no evidence of rilling. None of the eroded material left the uncut drainage. Slope length did not appear to be a causal factor in the differences because most of the rills on the clear-cut watershed were on short slopes, well within the range of slope lengths on the uncut watershed.

Activity: burning; clearing and tree harvest.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Menzel, B.W., and H.L. Fierstine. 1976. A study of the effects of stream channelization and bank stabilization on warmwater sport fish in Iowa: Subproject No. 5. Effects of long-reach stream channelization on distribution and abundance of fishes. Iowa Cooperative Fishery Research Unit, Iowa State Univ. USFWS, Office of Biological Services FWS/OBS-76-15. (ADF&G, Habitat Library, #B0998.)

Relationships between habitat characteristics and the distribution and abundance of fishes were studied in 11 natural and channelized warm-water stream segments of the upper Des Moines River Basin during the summers of 1974 and 1975. Four channelized prairie stream stations were characterized by a low degree of channel sinuosity, low gradient, and mainly sand bottom. Two natural prairie streams segments were highly sinuous, of low gradient, soft substrate, and with only a poorly defined pool-riffle sequence. Five woodland stream sites were of intermediate sinuosity, moderate-to-high gradient, firm bottom, and well-established pool-riffle sequence. Fishes were sampled by electroshocking from three to five times each year.

Catches were highly variable and there was no strong correlation between fish abundance and either stream sinuosity or gradient. Young-of-the-year fishes were most abundant in meandering stream segments. Species diversity was generally greatest in unchannelized woodland stream segments.

Marked fishes were recaptured in higher percentages in natural stream segments than in channelized areas. There was evidence for greater fish movement between proximate channelized stations than between natural areas. There is greater fish movement throughout straightened reaches. (Author's abstract: modified)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; alteration of natural cover - overhanging bank or shoreline.

Messieh, S.N., D. Wildish, and R.H. Peterson. 1981. Possible impact of sediment from dredging and spoil disposal on the Miramichi Bay herring fishery. Can. Tech. Rept. Fish. Aquat. Sci. 1008. 33 pp. (ADF&G, Habitat Library, #B0339.)

A field survey of the herring fishery in Miramichi Bay, N.B., Canada, is presented inclusive of catch statistics and fishing effort in the gill-net fishery. A spawning bed survey is described in relation to hydrographic conditions of the bay. Data from plankton surveys designed to plot concentrations of larval fish in the Miramichi estuary are also presented.

Results of experiments with herring eggs and larval fish show that a thin film of sediment deposited onto spawn will increase egg mortality. Eggs covered with 1 cm of sediment resulted in 100% mortality. Suspended sediments resulting from dredge disposal could result in earlier hatching and shorter hatching lengths and could inhibit feeding of herring larvae at levels down to a few parts per million. Juvenile herring avoid suspended sediments at concentrations as low as 2.5 mg/l, and thus dumping could result in low catches for individual gill nets near the dump site. Suggestions are presented to minimize the potential effects of dredging and dumping on the herring fishery in Miramichi Bay.

Activity: dredging; solid waste disposal.

Impact: addition of substrate materials; removal of substrate materials.

Meyers, T.F. 1977. Effects of logging study: a summary of NMFS activities. Unpubl. document. USDC, NMFS, Environmental Assessment Div., Juneau, AK. 60 pp. (ADF&G, Habitat Library, #B3528.)

The intertidal and subtidal habitat at the site of Rowan Bay log transfer facility was impacted by two phases of project activity: project construction and project operation. Construction phase impacts included the filling of intertidal habitat, the introduction increased sediment loading, and an increase in local turbidity. Following one season of log dumping and rafting, the impacts were extended into the subtidal habitat. Significant amounts of bark and wood debris covered the substrate directly off the dump face. The debris dispersed radially from the transfer structure with scattered wood debris occurring out to approximately 65 m. Evidence of settled wood debris was found 85 m out from the log transfer structure by sifting through the soft mud that generally covers the bottom of Rowan Bay below the 40 ft depth contour.

A decline in species strength and diversity was observed during the biannual investigations over the 1972-1975 study period. This study was not structured to quantify these changes or to define the correlation between project activities and coincident changes in the structure of local aquatic communities. However, it seemed evident that the production of infauna animals and attached algae was directly affected by the change in habitat. Epifauna organisms were also impacted, but, due to their more motile life form, it is possible these animals were affected indirectly through forced dispersal, loss of habitat, and changes in available food supplies.

Activity: log storage/transport.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; change in levels of other toxic compounds - bark or log leachates.

Miller, J.M. and B.M. Currin. 1981. Effects of a culvert on the hydrography and biology of North Carolina salt marsh. Part III. Highway Research Prog., N. Carolina State Univ., Raleigh, N.C. 71 pp. (ADF&G, Habitat Library, #B4152.)

A three year study of the effects of a culvert on the biota and tidal regime of a high, regularly flooded salt marsh showed the major hydrologic impact was to retard both the ebb (up to 7 h) and flood (up to 3 h) cycles and to decrease the minimum depth of water (up to 30 cm) in the marsh. Since the cross-section of the marsh is shaped like an inverted shallow pyramid, the area of the marsh inundated was exponentially reduced with a reduction in water depth. Although marshes differ considerably in hydrography, a reasonable estimate of the areal effect may be obtained with a few slope transects, but not with aerial photography. The retardation of water on the marsh may result in dissolved oxygen deficiencies, since the marsh surface sediments have high oxygen demands. The normal salinity cycle may be changed if there is significant freshwater input. Snails (Littorina irrorata) were restricted to the inundated surface, hence areally restricted by the culvert. Maximum abundances in the impacted (study) marsh ($170/m^2$) was about half of that in the adjacent control marsh ($300/m^2$). Zooplankton was not affected by the culvert, except in proportion to the volume reduction. Zooplankton samples were variable and probably do not represent a cost-effective indicator of environmental impact. Eighteen species of juvenile fish migrated into and out of the marsh on flood and ebb tides, respectively. These were dominated by spot (Leiostomus xanthurus) in winter and spring, and by gobies (Gobiidae) and anchovies (Anchoa sp.) in summer and fall. Their numbers were reduced in proportion to the volume reduction in the study marsh, but densities were similar to those in the control marsh. Therefore the culvert did not inhibit migratory behavior. Marsh access was shown to be important for feeding. Fish left the marsh, both day and night with fuller stomachs than when they entered. Feeding efficiencies were about ten times as efficient in the marsh than out. Recommendations are made to minimize the adverse impacts. (Authors abstract).

Activity: filling (aquatic and wetland habitats); stream crossing - structures.

Impact: change in depth or velocity of water; change in level of salinity.

Millikan, A., D. Penttila, and D. Day. 1974. Marine fish investigations progress report: Puget Sound baitfish study, July 1, 1973-June 30, 1974. Wash. Dept. Fish., Marine Fish Investigations, progress rept., Mgmt. and Research Div. (ADF&G, Habitat Library, #R4323.)

This study incorporated surveys of the spawning beaches of the surf smelt (Hypomesus pretiosus) in Puget Sound, Washington. Data were collected on distribution and intensity of the incubating spawn both laterally and vertically along the beach. Samples of incubating spawn were collected and analyzed for developmental stage, intensity of spawn, and mortality. Samples of spawning beach materials were collected for grain-size analysis. The spawning each surveys also involved the location of sites of proposed shoreline projects to determine the impact of such projects on the smelt spawning habitat at the sites. Previously unknown spawning areas utilized by surf smelt were identified. This information was used to determine supplementary bulkhead construction criteria to be implemented by the State of Washington in reviewing permits for shoreline alteration projects.

Activity: filling (aquatic and wetland habitats).

Impact: addition of substrate materials; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions.

Miossec, L. 1981. Effets de la pollution de l'Amoco Cadiz sur la morphologie et sur la reproduction des plies (Pleuronectes platessa) dans l'Aber Wrac'h et l'Aber Benoit. (Effects of Amoco Cadiz pollution on the morphology and reproduction of plaice (Pleuronectes platessa) in Aber Wrac'h and Aber Benoit.) In Amoco Cadiz, Fates and effects of the oil oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4336.)

Following the Amoco Cadiz oil spill, plaice Pleuronectes platessa from the Aber Benoit and the Aber Wrac'h showed fin erosion. The fluctuatioins in the percentage of diseased fish are compared with the degree of substrate contamination. Initial observations of plaice reproduction in the polluted abers are compared with research in the same area during 1967 and in the Bay of Douarnenez since 1976. These comparisons are based on studies of histology and gonado-somatic ratio and indicate alterations in ovary functions. (Author's abstract)

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Mitrovic, V.V, V.M. Brown, D.G. Shurben, and M.H. Berryman. 1968. Some pathological effects of sub-acute and acute poisoning of rainbow trout by phenol in hard water. Water Research, 2:249-254. Pergamon Press, Great Britian. (ADF&G, Habitat Library, #R3882.)

The authors describe some pathological changes found in rainbow trout poisoned by phenol concentrations near the 48-h LC_{50} level. Rainbow trout 1(+) yr old and 13-15 cm FL were exposed at a temperature of 12.6°C and pH 7.8 to one of four concentrations of phenol (6.5, 6.9, 7.3, 9.6 mg/l). The 48-h LC_{50} level for phenol under the test conditions was 7.5 mg/l (95% confidence interval = 6.6 to 8.5 mg/l). Fish were sampled after 2 h, 6 h, and immediately after death for the higher concentration phenol solutions. For the lower concentration solutions, the third sample period was 46 h in duration. Additionally, fish were left in the lower concentration solutions until they died, or for 7 d exposure.

Fish killed by phenol within a few hours showed, in some cases, internal haemorrhage (with accumulation of blood in the body cavity) and swelling of the spleen, as well as damage to the pharynx and gills. Haemorrhage also occurred at the bases of the fins, especially the pectoral and anal fins. Fish that survived 7 d showed signs of serious lesions. The skin was extremely slimy from excessive secretion of mucus, the gills were inflamed, and the outer surfaces of the gill arches showed injury, parts of the gill filaments, usually in the middle of the gill arch, being lost. These damaged areas (typically with much-shortened filaments) occurred on more than one arch and, for each set of gills, lay in the same line. The intestine was filled with a thick, yellow-green mucus mass, the gall bladder was completely full and distended, and in some cases, the liver had a blotched appearance with yellowish or dark spots. The spleen was usually enlarged and the kidney swollen, with a large area coloured white (possibly showing necrosis).

The authors provide a more detailed description of damage incurred by fish subjected to each level of phenol and at each time period tested. They concluded that the changes observed indicated that even at phenol concentrations below the 48-h LC_{50} (and the lowest concentration of which only 20% of the fish in 48 h were killed) sufficient damage was done within one week to possibly impair survival of an individual fish and affect reproduction by preventing the development of eggs.

Activity: filling (aquatic and wetland habitats); processing oil/gas; sewage disposal; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Mix, M.C., R.T. Riley, K.I. King, S.R. Trenholm, and R.L. Schaffer. 1977. Chemical carcinogens in the marine environment. Benzo(a)pyrene in economically-important bivalve mollusks from Oregon estuaries. Pages 421-431 in D.E. Wolfe, ed. Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems. New York: Pergamon Press. (ADF&G, Habitat Library, #R1347.)

Hydrocarbons are universal components of the marine environment and originate from marine organism biosysthesis and from pollution by fossil fuels and oil products. Benzo(a)pyrene (BAP) and several other polycyclic aromatic hydrocarbons (PAH), which are both carcinogenic and noncarcinogenic, are found in petroleum, and thousands of kg of these compounds enter the sea each year by many routes, including petroleum spills, runoff from roads, sewage, effluents from industrial processes and fallout from the atmosphere. The authors studied levels of BAP levels in economically important shellfish populations from several sites in five oregon bays. BAP levels were assayed in clams (Tresus capax, Saxidomus giganteys, Mya arenaria), mussels (Mytilus edulis), and oysters (Crassostrea gigas) from Tilamook, Netarts, Yaquina, Alsea, and Coos Bays. Detectable levels of BAP were present in bivalves from 38 of 44 sampling sites. High levels (greater than 15 ng/g) were present in mussels collected from the Newport bayfront in Yaquina Bay and from a marina in Tillamook Bay. The sources of BAP in these mussels was not determined, but the authors tested creosote levels in the pilings from which mussel samples were collected. The results suggested thaht creosote may not have been the major source of BAP. Significant levels (greater than 5 ng/g) were present in M. arenaria collected from an area adjacent to the shipping docks in Coos Bay.

Activity: filling (aquatic and wetland habitats); processing oil/gas; transport of oil/gas/water - land; transport of oil/gas/water - water; transport personnel/equipment/material - land.

Impact: change in levels of hydrocarbons.

Mock, C.R. 1966. Natural and altered estuarine habitats on penaeid shrimp. Pages 86-89 _in_ Proceedings of the Gulf Caribbean Fisheries Inststitute. 19th Ann. Sess. Contrib. No. 223, Bureau Commercial Fisheries, Biological, Galveston, Texas. (ADF&G, Habitat Library, #R3823.)

This study demonstrates what can happen to a shrimp nursery area when it is altered by bulkheading. Two areas were chosen--one adjacent to an unaltered vegetative shore and the other near a concrete bulkhead. Both had similar hydrology and sediment types but differed in the amount of organic detritus in the bottom sediments and in water depth. Intensive sampling over a 10-mo period produced 2.5 times more brown shrimp (_Penaeus aztecus_) and fourteen times more than white shrimp (_P. setiferus_) from the natural habitat than the bulkheaded area. This preference for the unaltered habitat depended on the physical rather than the hydrologic characteristics of the habitat. (Author's abstract).

Activity: filling (aquatic and wetland habitats).

Impact: addition of substrate materials; addition of physical barriers - partial obstructions.

Moles, A. 1980. Sensitivity of parasitized coho salmon fry to crude oil, toluene, and naphthalene. Trans. Am. Fish. Soc. 109(3):293-297. (ADF&G, Habitat Library, #R3689.)

The effect of parasitism by glochidia (parasitic larvae) of Anodonta oregonensis (a freshwater mussel) on the sensitivity of coho salmon fry, Oncorhynchus kisutch, to oil was determined. Coho fry with different levels of parasitism were exposed to several concentrations of either the water-soluble fraction of Prudhoe Bay crude oil or the aromatic hydrocarbons toluene and naphthalene. Fry infested with 20-35 glochidia were significantly (P less than 0.05) more sensitive to each of the toxicants than uninfected fish. Sensitivity increased linearly with increased parasite numbers. Thus, an oil spill during the summer when coho fry are carrying glochidia could have a greater effect at lower concentrations than would be predicted from standard toxicity tests with nonparasitized fish. For this reason, interpretation and application of results of toxicity tests should take into account the kinds and intensities of parasitism found both in test animals and in the wild populations of fish.

Activity: drilling; processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Moles, A., and J.J. Pella. 1984. Effects of parasitism and temperature on salinity tolerance of the kelp shrimp Eualus suckleyi. Trans. Am. Fish. Soc. 113:354-359. (ADF&G, Habitat Library, #R3693.)

Mortality of the kelp shrimp Eualus suckleyi was determined over a range of salinity and temperature combinations in the laboratory. At every acclimation temperature, mortality increased with a decrease in salinity. Kelp shrimp acclimated to 4°C tolerated salinity shocks better than animals acclimated to higher or lower temperatures. Parasitism by the bopyrid isopod Bopyroides hippolytes reduced tolerance to salinity change over the range of temperatures examined. (Authors abstract)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in level of salinity.

Moles, A., and S.D. Rice. 1983. Effects of crude oil and naphthalene on growth, caloric content, and fat content of pink salmon juveniles in seawater. Trans. Am. Fish. Soc. 112:205-211, 1983. (ADF&G, Habitat Library, #R3690.)

The authors of this paper identified a number of studies that document that crude-oil-contaminated water can inhibit growth of fish. They briefly describe the life history cycle of pink salmon and explain that salmon are most vulnerable to oil contamination during the juvenile stage when they first enter the coastal marine areas from freshwater streams. This introduction is followed by a discussion of a laboratory study they completed relative to juvenile fish growth in oil-contaminated waters.

In the study, juvenile pink salmon, <u>Onchorhynchus gorbuscha</u>, were exposed for 40 d to stable, sublethal concentrations of naphthalene (less than 0.80 mg/l) and the water-soluble fraction of Cook Inlet crude oil (less than 0.87 mg/l total aromatic hydrocarbons). Concentrations (percentage of the 96-h LC_{50}, median lethal concentration) of 10% naphthalene and 14% water-soluble fraction of crude oil did not affect wet weight or length of exposed fish. At higher concentrations, however, growth per day determined from wet weight decreased with increased toxicant concentration. Change in length of the fish was not a sensitive measure of toxicity. Fish exposed for 40 d to concentrations of toxicants as low as 33% of the 96-h LC_{50} weighted significantly less than control fish (P is less than 0.05). Juveniles exposed to the water-soluble fraction of crude oil had slower growth rates than those exposed to the same concentration (percentage of the LC_{50}) of naphthalene. Fish exposed to either naphthalene or the water-soluble fraction of crude oil had decreased caloric content; however, fat content of the fish was not affected. Chronic marine oil pollution at a concentration as low as 0.40 mg/l total aromatic hydrocarbons could reduce growth of juvenile pink salmon.

Activity: drilling; processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Moles, A., S.D. Rice, and S. Korn. 1979. Sensitivity of Alaskan freshwater and anadromous fishes to Prudhoe Bay crude oil and benzene. Trans. Am. Fish. Soc. 108(4):408-414. (ADF&G, Habitat Library, #R3692.)

The purpose of this study was to determine the sensitivity of the eggs, alevins, fry, juveniles, and smolt of several freshwater and anadromous fishes to the water-soluble fractions of Prudhoe Bay crude oil and benzene. Specific objectives were to 1) determine the sensitivity of the freshwater resident (40-75 mm long) of eight common Alaskan fishes (coho salmon, chinook salmon, sockeye salmon, Dolly Varden, arctic char, arctic grayling, slimy sculpin, and threespine stickleback), 2) determine differences in sensitivity of the eggs, alevins, and fry of pink and coho salmon, and 3) determine sensitivity of out-migrants of three species (pink and sockeye salmon and Dolly Varden) in fresh water and sea water. Results of the tests are as follows:

1. <u>Species sensitivity to oil and benzene</u>. The salmonids (40-75 mm long) were consistently the most sensitive species tested with both the water-soluble fraction of Prudhoe Bay crude oil and benzene, and threespine sticklebacks were consistently the most tolerant. Slimy sculpin were similar to salmonids in sensitivity. Median tolerance limits (TLms; the concentration in which half the animals survive a given period of exposure, which in these tests was 96 h) of the salmonids for crude oil ranged from 2.7 to 4.4 mg/l; TLms of benzene ranged from 11.7 to 14.7 ul/l. Threespine sticklebacks and, to a lesser extent, slimy sculpins were more tolerant than salmonids and had larger TLms: threespine sticklebacks had a crude-oil TLm of 10.4 mg/l and a benzene TLm of 24.8 ul/l; slimy sculpins had a crude-oil TLm of 6.44 mg/l and a benzene TLm of 15.4 ul/l.

2. <u>Sensitivity of early life stages</u>. The sensitivities of pink and coho salmon to benzene increased sharply during development from egg to fry. Eggs were quite tolerant to benzene (TLm = 339 and 542 ul/l for pink and coho respectively); the alevin stages were moderately sensitive to benzene; and the emergent stage was the most sensitive to benzene (TLm = 12.3 ul/l for coho salmon and 17.1 ul/l for pink salmon).

   The eggs and early alevins (20 d posthatching) tested were quite tolerant to crude oil (TLm greater than 12 mg/l). However, it has been noted by one author (Rice 1981) that judging the sensitivities of developing fry embryos to oil contamination is difficult because they may outwardly appear viable when they have been severely affected. Some extremely deformed embryos continue to develop and temporarily survive. Because of this, embryos may be judged to be disproportion-ately more "tolerant" when evaluated only in terms of survival (as in the above study). Emergent fry were sensitive to Prudhoe Bay crude oil with a 96-h TLm of 8 mg/l for both species.

3. <u>Sensitivities of out-migrants in fresh water and sea water</u>. Out-migrants of pink salmon, sockeye salmon, and Dolly Varden acclimated to sea water were about twice as sensitive to benzene and the water-soluble fraction of Prudhoe Bay crude oil as out-migrants tested in fresh water, apparently because of the additional stress of entering sea water and the physiological changes associated with this transition. Freshwater TLms were 2.3 to 8.0 mg/l for crude oil and 10.8 to 17.1 ul/l for benzene. Corresponding seawater sensitivities were 1.1 to 3.6 mg/l for crude oil and 5.5 to 8.5 ul/l for benzene.

Activity: drilling; processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Moles, D.A., S. Bates, S.D. Rice, and S. Korn. 1981. Reduced growth of coho salmon fry exposed to two petroleum components, toluene and naphthalene, in fresh water. Trans. Am. Fish. Soc. 110:430-436. (ADF&G, Habitat Library, #R3691.)

Coho salmon, Oncorhynchus gorbuscha, fry were exposed 40 d to stable, sublethal concentrations of toluene (0.4, 0.8, 1.6, 3.2, 5.8 ml/l) and naphthalene (0.2, 0.4, 0.7, 1.4 ml/l) in fresh water. All fry were fed equal daily rations of Oregon Moist Pellet Formula II. Dry weights, wet weights, and lengths of fry exposed to the two highest concentrations of each toxicant for 40 d were significantly less than controls ($P < 0.01$). Growth per day, determined from weights and lengths, decreased linearly with increased concentrations. Fry exposed to naphthalene had a slower growth rate than fry exposed to equivalent concentrations (percentage of the 96-h median lethal concentration of LC_{50}) of toluene. Concentrations 18% of the LC_{50} of naphthalene and 26% of the LC_{50} of toluene had no effect on dry weight, wet weight, or length of exposed fry. (Author's abstract)

Activity: drilling; processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Moore, J.W., and D.J. Sutherland. 1981. Distribution of heavy metals and radionuclides in sediments, water, and fish in an area of Great Bear Lake contaminated with mine wastes. Arch. Environm. Contam. Toxicol. 10:329-338. (ADF&G, Habitat Library, #R3811.)

The concentrations of heavy metals and radionuclides in the sediments and water of Great Bear Lake were determined during 1978 near an operating silver mine and an abandoned uranium mine. Additional information on the level of mercury in fish tissues were also collected. The mines, situated on the same site, deposited tailings and other waste material directly into the lake. The concentrations of mercury, lead, manganese, and nickel in the sediments were highest near the tailings deposit and decreased significantly as the distance from the mine increased. Although there were also significant positive correlations between these metals and the organic content of the sediments, water depth and slope of the bottom had no impact on metal distribution. Since the concentrations of arsenic, cobalt, copper, ^{226}radium, ^{210}lead and ^{230}thorium varied inconsistently throughout the study area, the distribution of these substances could not be related to any of the environmental factors that were measured. There were, however, significant negative correlations between the concentrations of ^{232}thorium and ^{228}thorium and distance from the mine and organic content of the sediments. Heavy metal and radionuclide levels in water were generally below detectable limits, reflecting the strong chemical bonding characteristics of the sediments. The low concentrations of mercury in the tissues of lake trout were probably related to low uptake rates and the ability of this species to move into uncontaminated areas of the lake. (Author's abstract)

Activity: solid waste disposal.

Impact: addition of substrate materials; change in levels of heavy metals; change in levels of other toxic compounds - other.

Moring, J.R. 1982. Decrease in stream gravel permeability after clear-cut logging: an indication of intragravel conditions for developing salmonid eggs and alevins. Hydrobiologia 88(3):295-298. (ADF&G, Habitat Library, #R3829.)

Average gravel permeabilities decreased significantly in an Oregon stream after 82% of the drainage basin was clear-cut. Patterns remained statistically normal in a stream of an unlogged drainage basin and in a stream in a drainage area that was 25% clear-cut, but that had riparian buffer strips about 30-m wide left along the stream. It is cautioned that decreases in yearly permeability values can reflect adverse intragravel conditions for developing salmonid eggs and alevins, even if other environmental changes, particularly the amount of sediment fines in gravel, are not as apparent. (Author's abstract, modified)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Nece, R.E., E.B. Welch, and J.E. Reed. 1975. Flushing criteria for salt water marinas. Dept. Civil Eng., Univ. Wash., Tech. Rept. No. 42. Seattle, WA. 50 pp. (ADF&G, Habitat Library, #R3818.)

Water quality problems, such as noticeable densities of plankton algae and subsequent reduction in dissolved oxygen content, were observed in only one of four studied marinas. A plankton algal bloom reached at least 25 ug/l chl a in one section of Lagoon Point Marina and was followed by dissolved oxygen content as low as 2 mg/l. This occurred in one section of the poorly flushed, closed end of the marina. From these observations and an assumed maximum plankton growth rate of 100% per day, NO_3-N as the limiting nutrient and 50% of surface intensity as optimum for light, the expected maximum steady state plankton biomass was estimated for varying mixing depths (mean depth of marina) and dilution rates. The observed plankton biomass was very close to what would be expected from a marina like Lagoon Point that has a 2.5 m mean depth and dilution rate predicted to be as low as 10% per day in some sections from a physical scale model.

From these findings, criteria are suggested such that to avoid water quality problems of this type the dilution rate should be at least 30% per day and the depth 2 m. If 1 m deeper, dilution could be as low as 10% per day, but increasing depth to avoid problems is probably not as effective as increasing dilution rate because of potentially reduced mixing depths from thermal stratification in poorly flushed deeper situations.

Physical scale models are considered to be the most reliable method to determine if dilution rates for a given marina are acceptable, because of the present inadequacy of mathematical models. (Author's abstract)

Activity: dredging; filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in level of dissolved oxygen, nitrogen; change in level of salinity; change in levels of nutrients.

Narver, D.W. 1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. Fish. Mar. Serv. Tech. Rept. 323. 55 pp. (ADF&G, Habitat Library, #B0049.)

The objective of this report was to compare fish populations, invertebrate drift, stream temperatures and stream channel widths in recently clear-cut and burned stream sections and adjacent upstream sections in standing timber.

Late summer standing stock estimates of the trout population in Jump Creek was considerably greater in the timbered (2,226 fish/acre and 38.8 lb/acre) than the logged section 1,420 fish/acre and 3.9 lb/acre). The standing stock of juvenile coho salmon and steelhead in Wolf Creek ranged from 6,722 fish/acre (27.9 lb/acre) to 10,206 fish/acre (49.8 lb/acre), with the highest density (mainly steelhead) in the logged sections. Stock estimates for these two streams are similar or higher in comparison to other stream salmonid populations reported in the literature.

Other possible effects of logging revealed in this survey were fish size, stream temperature, and stream channel width. A larger average size of each age group of trout in the logged section of Jump Creek compared to the timbered section may have been related to higher stream temperatures in June and July, leading to faster development of preemergent fry and earlier emergence. Stream temperature in the logged sections was higher than in upstream timbered sections. In Jump Creek maximum temperature was 21.1°C (70.0°F in the logged section and 15.1°C (59.2°F) in the timbered section; temperatures over 20°F (68°F lasted only a few hours each day. The channel of both streams in the logged sections appeared badly eroded with cutbanks and wide gravel bars, but only in Wolf Creek was the channel significantly wider in the logged than the timbered sections. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in depth or velocity of water; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

Narver, D.W. 1971. Effects of logging debris on fish production. Pages 100-111 in J.T. Krygier and J.D. Hall, eds. Proceedings of a symposium on forest land uses and stream environment, October 19-21, 1970, Oregon State Univ., Corvallis, OR. (ADF&G, Habitat Library, #R5084.)

Stream salmonids (eight species of Pacific salmon, trout, and char) are discussed in relation to their environmental requirements and the possible impact of logging debris on their production. The emphasis is on small streams because of their great importance as nursery and spawning areas for certain species and because they may be more susceptible to damage than larger streams or rivers. Extensive use is made of pertinent literature. It is concluded that accumulations of logging debris in small streams can have serious consequences on the production of salmonid fishes. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen.

Nakai, O. 1977. Turbidity generated by dredging projects. Pages 31-47 in Management of bottom sediments containing toxic substances: proceedings of the third U.S.-Japan experts' meeting-November 1977. (ADF&G, Habitat Library, #R3813.)

This paper discusses investigations into turbidity generated by dredging during port construction. Field investigations were conducted to develop a method for predicting the quantity of turbidity generated by various dredges in different kinds of soil. A turbidity generation unit (TGU) was calculated using the results of these studies. It is defined as the quantity of turbidity generated per unit volume of dredged material and can be effectively used to predict the quantity of turbidity.

Grab dredges having a bucket volume of 8 m^3, operating in silty clay, were found to produce the highest TGU. Pump dredges having 2,000 horse-power, operating in sand, produced the lowest TGU.

Activity: dredging.

Impact: change in turbidity or suspended sediments.

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

NOAA (National Oceanic and Atmospheric Administration). 1980. Seafood waste discharges off Amaknak Island, Alaska: report of field investigations. NMFS, Environmental Assessment Division, Juneau, AK. 37 pp. (ADF&G, Habitat Library, #B1724.)

Seafood processors in the Dutch Harbor/Unalaska area have been unable to conform to EPA criteria for discharge of waste, which require that accumulations of waste within 98 ft of the outfall must be less than three inches deep. In an attempt to alleviate this problem, some processors have shortened their disposal lines so that wastes are being discharged just below the intertidal zone, where it is hoped tidal action will increase dispersal. In this study, biologists conducted a preliminary survey of seafood waste outfalls from both intertidal and deep-water discharges off Amaknak Island during April 14-21, 1980. Summaries of dynamics associated with both deep water and intertidal discharges are presented. Dispersal of ground crab waste is a function of depth; wave climate; the density, shape, and size of shell; the discharge location; and the volume and frequency of waste discharged. Seafood wastes released into deep water tend to accumulate into piles because they are relatively unaffected by tidal energy forces. Distribution of material at these locations is influenced most by bottom topography. Organisms unable to escape the advancing blanket of material are subject to smothering. Recolonization of active debris piles is severely limited. Abandoned piles reportedly begin to undergo recolonization by infaunal species after three years.

A second impact zone occurs outside the area directly covered by the debris pile. The boundaries of this zone are more difficult to define and possibly change in size according to seasonal variations in waste discharge rates and environmental conditions. Organisms in this zone are also subject to smothering by seafood waste. In addition to direct smothering, deposited materials eliminated attachment sites for benthic organisms. In elevated areas where attachment sites were still exposed, divers observed remains of colonies of attached organisms such as Pododesmus sp. The cause of death was not known. Recolonization of this impact zone does occur but is limited by the recurrence of stressful conditions and suitable attachment surfaces. Water quality conditions were not measured in this study. It appears, therefore, that the large, decaying waste deposits that persist year after year at deeper (greater than 42 ft) discharge sites can be avoided by adopting shallower nearshore outfall locations. The two key variables determining the effectiveness of shallow-water discharge in dispersing ground crab waste are location and depth of discharge. The authors, however, note that shallow-water discharge is not free of problems and may have an adverse impact upon the intertidal and subtidal communities in the area. The shallow-water discharge should not be allowed in the Unalaska area until more comprehensive data become available.

Myren, R.T., and R.J. Ellis. 1984. Evapotranspiration in forest succession and long-term effects upon fishery resources: a consideration for management of old-growth forests. Pages 183-186 in W.R. Meehan, T.R. Merrell, and T.A. Hanley, eds. Fish and wildlife relationships in old-growth forests. Symposium proceedings, Juneau, Ak, 12-15 April 1982, Am. Inst. Fish. Res. Biol. (ADF&G, Habitat Library, #R4988.)

Evapotranspiration of rapidly growing forests may markedly reduce the minimum streamflows during the summer. In many streams of Southeast Alaska, the minimum summer streamflows limit spawning success of pink and chum salmon and may limit the habitat of species such as coho salmon that rear in streams. Extrapolating from the literature leads to the conclusion that converting significant portions of old-growth watersheds to rapidly growing second-growth forests risks permanently reducing summer low flows of the streams and, thus, their ability to produce salmon. It is recommended that this risk be considered in managing the forests and that effects on streamflow of converting old-growth forests to second-growth forests be included in studies of logging in Southeast Alaska. (Authors abstract)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water.

Myrberg, A.A. 1978. Ocean noise and the behavior of marine animals: relationships and implications. Pages 169-208 in J.L. Fletcher and R.G. Busnel, eds. Effects of noise on wildlife. New York: Academic Press. (ADF&G, Habitat Library, #R3190.)

Myrberg cited studies showing that ambient noise could mask the detection of sound by fishes. He stated that traffic and industrial noise can constitute a major source of noise between 10 and 1,000 Hz, which is the most important range of sound detection in most fishes. Myrberg gave examples that showed that the success of reproduction and predation may depend on the level of environmental noise. The noise can mask the sounds that fish use in communication. There is some evidence to show that fish may have hearing loss when subjected to very noisy environments for long periods of time. Other species of fish may avoid or leave such noisy environments.

Activity: blasting; drilling; human disturbance; transport of oil/gas/water - water; transport personnel/equipment/material - water.

Impact: increase in hydrostatic pressure or noise.

Murray, A.J., and M.G. Norton. 1982. A field assessment of effects of dumping wastes at sea:10. Analysis of chemical residues in fish and shellfish from selected coastal regions around England and Wales. Fish Res. Tech. Rept. No. 69. Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research, Lowestoft, England. 42 pp. (ADF&G, Habitat Library, #B6226.)

This report contains the results of the fish and shellfish monitoring programs conducted by the Ministry of Agriculture, Fisheries and Food. Surveys were conducted to monitor the effects of dumping nonradioactive wastes at sea. Particular contaminants that were measured included mercury, cadmium, lead, zinc and copper, lindane, dieldrin, DDT (and its metabolites), and polychlorinated biphenyls (PCBs).

Although none of the concentrations of contaminants was of concern as a threat to public health, the surveys revealed that commercial species of fish and shellfish contained elevated levels of several types of contaminants in areas where sewage-sludge dumping occurred. In some areas tested, however, additional contamination from coastal dishcarges and atmospheric deposition made it impossible to verify the caustative agent of contamination of the biota.

Activity: solid waste disposal.

Impact: change in levels of heavy metals; change in levels of biocides; change in levels of other toxic compounds - other.

Murphy, M.L., C.P. Hawkins, and N.H. Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. Tran. Am. Fish. Soc. 10:4. 469-478. (ADF&G, Habitat Library, #R3030.)

Small streams differing in sediment composition were compared in logged and forested reaches to determine the effects of accumulated fine sediment on stream communities under different trophic conditions. Three stages of forest community succession were studied in the Cascade Mountains: recently clear-cut areas without forest canopy (5-10 yr after logging); second-growth forest with deciduous canopy (30-40 yr after logging); and old-growth coniferous forest (greater than 450 yr old). One stream with mostly coarse sediment (56-76% cobble) and one with more fine sediment (5-14% sand and 23-53% gravel) were contrasted for each successional stage. In general, streams traversing open clear-cuts had greater rates of microbial respiration and greater densities or biomasses of aufwuchs, benthos, drift, salamanders, and trout than did the shaded, forested sites regardless of sediment composition. The authors conclude that, for the streams studied, changes in trophic status and increased primary productivity resulting from canopy removal may mask or override the effects of sedimentation. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Murphy, M.L., and J.D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Can. J. Fish. Aquat. Sci. 38:137-145. (ADF&G, Habitat Library, #R3615.)

Assemblages of aquatic vertebrate and insect predators were inventoried in streams in old-growth and logged coniferous forests in western Cascades of Oregon to assess effects of clear-cut logging on stream communities. Effects associated with logging depended on stream size, gradient, and time after harvest. Clear-cut sections where the stream was still exposed to sunlight (5-17 yr after logging) generally had greater biomass, density, and species richness of predators than old-growth (more than 450 yr old) forested sections. Increases were greatest in small (first-order), high gradient (10-16%) streams, where clear-cut sites had both greater periphyton production and coarser streambed sediment than old-growth sites of similar size and gradient. Effects on predators were mixed in larger, lower gradient streams, where clear-cut sites showed accumulation of sediment and relatively small increases in periphyton production. Second-growth logged sections (12-35 yr after logging), reshaded by deciduous forest canopy, had lower biomass of trout and fewer predator taxa than old-growth sites. (Author's abstract)

Activity: clearing and tree harvest.

Impact: addition of substrate materials; alteration of natural cover - riparian vegetation.

Murphy, M.L. 1985. Die-offs of pre-spawn adult pink salmon and chum salmon in southeastern Alaska. N. Am. J. Fish. Mgmt. 5:302-308. (ADF&G, Habitat Library, #R5030.)

About 300 prespawn adult pink salmon (Oncorhynchus gorbuscha) and chum salmon (Oncorhynchus keta) died in August 1981 in the intertidal reach of Porcupine Creek, a small stream in an old-growth forest. A combination of low stream flow and neap tides triggered the die-off, and about 1% of the pink salmon and chum salmon spawners died upon returning to Porcupine Creek in 1981. Anoxia, rather than temperature, caused most of the deaths because the maximum stream temperature was 19°C - well below lethal temperatures. Conditions similar to those in 1981 recur in Porcupine Creek about once every 8 yr. This type of die-off also appears to be common in other streams in southeastern Alaska and can be predicted from the number of salmon returning, the amount of precipitation, and the height of the tide. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; change in level of dissolved oxygen, nitrogen.

Mulvihill, E.L., C.A. Francisco, J.B. Glad, K.B. Kaster, and R.E. Wilson. 1980. Biological impacts of minor shoreline structures on the coastal environment: state of the art review. Vols. 1 and 2. USFWS Biol. Ser. Prog. USFWS/OBS-77/51. (ADF&G, Habitat Library, #B0160.)

The authors reviewed 555 papers on the biological impacts of breakwaters, jetties, groins, bulkheads, revetments, ramps, piers, buoys and floating platforms, harbors for small craft, and bridges and causeways. Structures that had the greatest potential for impacting the coastal environment were small boat harbors, bridges and causeways, bulkheads, and breakwaters and jetties. Low-impact-potential structures include buoys and floating platforms, piers, and pilings. Descriptions of certain impacts recurred throughout the literature. Examples of the more significant recurrent impacts are as follows:

- Changes shoreline dynamics
- Affects littoral transport
- Changes wave energy
- Changes sediment composition
- Increases turbidity
- Causes suspension of toxic chemicals
- Changes dissolved oxygen, salinity, or temperature
- Shades the water
- Affects circulation patterns
- Alters existing habitat or creates new habitat
- Alters species composition
- Affects migration patterns
- Socioeconomic changes due to increased area usage

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen; change in level of salinity; introduction or removal of species.

Moyle, P.G. 1976. Some effects of channelization on the fishes and invertebrates of Rush Creek, Modoc County, CA. Calif. Fish. and Game 62(3):179-186. (ADF&G, Habitat Library, #R5104.)

Channelized and unchannelized sections of the lower 7 km (4.3 m) of Rush Creek, Modoc County, California, were compared to determine the impact of channelization on fish populations, especially those of trout (Salmo gairdneri and S. trutta) and the rare endemic Modoc sucker (Catostomus microps), and invertebrate populations. Fish were captured with a backpack electrofisher, which provided a representative sample by numbers of the species present, although large fish were more vulnerable to capture than small fish. Channelized sections contained fewer and smaller trout, as well as a lower biomass, than the unchannelized sections. Modoc sucker numbers and biomass were also lower in the channelized sections. Only Pit sculpin (Cottus pitensis) were consistently more numerous in the channelized sections. Overall, total fish biomass in the channelized sections was less than one third of that in the unchannelized sections. The biomass of invertebrates in the channelized sections was found to be less than one third of that in the unchannelized sections. The invertebrate species composition of the two areas was also different. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; introduction or removal of species.

Moulton, L.L., B.J. Gallaway, M.H. Fawcett, W.B. Griffiths, K.R. Critchlow, R.G. Fechhelm, D.R. Schmidt, and J.S. Baker. 1985. 1984 Central Beaufort Sea Fish Study, waterflood monitoring program fish study. Draft final rept. Envirosphere Company, Anchorage, AK. (ADF&G, Habitat Library, #B6561.)

The 1984 Central Beaufort Sea Fish Study focused on West Dock-induced alterations to fish habitat, to habitat utilization patterns (including utilization of prey), and to migratory movements of anadromous fish. The study area extended from the west side of the Kuparuk River delta to the Sagavanirktok River delta. The program consisted of daily fyke net sampling of fish throughout the open-water period at 25 stations plus daily sampling for shorter periods at two additional stations near the Sagavanirktok delta. Additional data collected included water quality measurements and drop net samples of epibenthic and pelagic prey taken daily near each fyke net, a mark/tag recapture study of the four key anadromous fish species (arctic cisco, least cisco, broad whitefish, and char), diel sampling conducted four times during the summer at selected stations, and broad-scale collection of fish stomachs periodically throughout the open-water season.

The majority of the char, broad whitefish, and small arctic cisco in the study area apparently dispersed from wintering areas in the Sagavanirktok River or delta while least cisco and large arctic cisco moved into the area after overwintering in the Colville River delta. Many of the large broad whitefish and juvenile arctic cisco caught at stations west of the West Dock causeway likely came from overwintering areas in the Colville delta. Results for arctic cisco are consistent with the hypothesis that most, if not all, of the arctic cisco in the study area originate from a spawning stock in the Mackenzie River.

In 1984, small arctic cisco, broad whitefish, and char tended to remain within Prudhoe Bay, with little western dispersal into the Gwydyr Bay lagoon system. Small least cisco tended to remain within the Gwydyr Bay lagoon system. These patterns appeared to be caused, at least in part, by the presence of West Dock causeway, which apparently hindered east-west movement of small anadromous fish into and out of the lagoon system. In contrast, large arctic cisco, least cisco and char moved widely throughout the study area, while large broad whitefish tended to remain near the river deltas. (Authors' abstract: partial)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; change in turbidity or suspended sediments; alteration of natural cover - aquatic vegetation; change in levels of nutrients.

Mosley, M.P. 1982. Analysis of the effect of changing discharge on channel morphology and instream uses in a braided river, Ohau River, New Zealand. Water Resour. Res. 18(4):800-812. (ADF&G, Habitat Library, #R2318.)

Constant discharges of 26.5, 56.7, 105, 240, and 507 $m's^{-1}$ were released down the Ohau River from Ohau, a power station, and measurements of water depths and mean velocities made along cross-sections in a braided section of the channel. Frequency distributions of water depth and velocity are presented both singly and jointly for each discharge; the methods used provide much more information on the changing character of the river than is provided by conventional hydraulic geometry relations. As discharge increases, existing channels become wider, deeper, and faster and frequently merge to become a single larger channel. However, additional channels are generated with the same characteristics as those existing at lower discharges, and the total number of channels at a cross-section remains constant. Hence, the increase of water surface area tends to be an addition of faster, deeper water. In some respects, then, the braided river is morphologically more stable than a single-thread river.

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water.

Morton, J.W. 1977. Ecological effects of dredging spoil disposal: a literature review. USFWS Tech. Pap. No. 94. 37 pp. (ADF&G, Habitat Library, #B0994.)

This paper summarizes the effects of physical, chemical, and biological components of dredging and spoil disposal in estuaries. A physical effect of dredging and open-water spoil disposal is alteration of circulation patterns that result when dredged channels and spoil mounds reroute tidal currents, induce shoaling, or alter flushing rates. A second important effect is the uncontrolled redistribution of sediments eroded from the spoil mound at the disposal site.

Changes in sediment chemistry at dredging and disposal sites and of the water overlying these areas result from dredging and dumping, especially if the dredged sediments have a high organic content or are contaminated. Several interacting factors and processes are believed to control the flux of contaminants across the sediment-water interface: the clay and organic content, redox (oxygen-reduction) potential, pH, bacteria, the sulfur cycle, and the iron cycle. A conceptual model of these variables interactions is presented.

Although direct burial of organisms and destruction of habitat are two obvious biological effects of dredging and dumping, the effects can be reduced by careful timing of the dredging and placement of the spoil.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of hydrocarbons; change in levels of nutrients.

Morris, L.A., R.N. Langemeier, T.R. Russell, and A. Witt Jr. 1968. Effects of main stem impoundments and channelization upon the limnology of the Missouri River, Nebraska. Trans. Am. Fish. Soc. 97(4):380-388. (ADF&G, Habitat Library, #R1330.)

Rigid control has been imposed upon the Missouri River by impounding over one-half of the upper 1,500 m and by channeling most of the remaining river within permanent, narrow banks. These controls have caused environmental changes in the lower Missouri River, as shown by this study of adjacent unchannelized and channelized sections of river below the main stem impoundments. Impoundments have regulated flow by evening maximum and minimum discharges and improved downstream water quality by decreasing turbidity and indirectly raising the dissolved oxygen. In addition the impoundments have contributed a limnetic cladoceran, <u>Leptodora kindti</u>, to the drift and have affected the distribution of benthos through the modification of turbidity.

Channelization of the river has reduced both the size and variety of aquatic habitat by destroying key productive areas. Average standing crops of benthos were similar in unchannelized and channelized river (0.63 and 0.67 lb/acre, respectively), but the benthic area had been reduced 67% by channelization. In the channelized river, the average standing crop of drift was 8 g/acre-ft, while in the unaltered river the average standing crop was 68 g/acre-ft. There was little similarity between the organisms of the drift and benthos; however, there was similarity between the organisms in the drift and the aufwuchs. (Authors' abstract)

Activity: channelizing waterways; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water.

Neff, J.M., and J.W. Anderson. 1981. Response of marine animals to petroleum and specific petroleum hydrocarbons. Applied Science Publishers, London. 177 pp. (ADF&G, Habitat Library, #B2668.)

Neff and Anderson review and summarize lethal and sublethal effects of oil on marine organisms and discuss the results of their own laboratory studies. Major topics include source and distribution of hydrocarbon pollution, toxicity of hydrocarbons, effects of hydrocarbons on reproduction, development and growth, accumulation and release of petroleum hydrocarbons, and the effects of petroleum on the behavior of marine organisms. The organisms studied include polychaetes, sea urchins, corals, mollusks, and fish.

The estuarine fish Cyprinodon variegatus, Fundulus heteroclitus, and F. similis were exposed to the water-soluble fraction of oil from immediately after fertilization to 130 h of development. These experiments showed that the early cleavage stages of newly fertilized eggs are somewhat less sensitive to pollutants than gastrula and later stages. The heart beat rates in the fish embryos were depressed by oil concentrations approaching acutely toxic levels. The experiments have shown that embryos of estuarine mollusks and fish are tolerant to petroleum hydrocarbons. Relatively high concentrations are required to produce significant mortality or a delay in development. If the exposure to potentially lethal concentrations of oil was terminated early enough, the embryos could recover and resume normal development.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Neill, W.H., R.G. Fechhelm, B.J. Gallaway, J.D. Bryan, and S.W. Anderson. 1983. Modeling movements and distribution of arctic cisco (Coregonus autumnalis) relative to temperature-salinity regimes of the Beaufort Sea near the waterflood causeway, Prudhoe Bay, Alaska. Biol. Pap. Univ. Alaska No. 21:39-61. (ADF&G, Habitat Library, #R3957.)

A mechanistic model was developed to evaluate the movement patterns of small arctic cisco relative to environmental heterogeneity associated with the Waterflood Causeway, a gravel pier that projects 3.9 km into the Beaufort Sea from the Alaskan coast near Prudhoe Bay. Fish movement and resultant changes in density were treated as a donor-controlled drift process biased by experimentally determined temperature preferences (given temperature and salinity acclimation) of the fish. Simulated fish density was significantly rank-correlated with actual catch. Goodness-of-fit was improved when observed data were filtered to remove the effects of presumed high-frequency changes in fish catchability.

Under the assumption of model validity, small arctic cisco make appropriate use of the causeway's breach as a passageway. Causeway-induced variation in water quality during August 1981 directed fish movement in a manner that should reduce entrainment and impingement potential of planned water-intake structures, although these same water quality differences resulted in an estimated 7% reduction in fish density that would have been present in the area had environmental heterogeneity provided no directional bias in fish movements. (Author's abstract)

Activity: filling (aquatic and wetland habitats).

Impact: addition of physical barriers - partial obstructions.

Nelson, W.R., and L.G. Beckman. 1980. Entrainment of ichthyoplankton by irrigation withdrawal systems. USFWS Bio. Serv. Prog. FWS/OBS-79/16. (ADF&G, Habitat Library, #B6271.)

A field study was conducted on an embayment of the Missouri River in South Dakota to determine the effect of depth and location of irrigation pumps on entrainment. One system was operated at a shallow site with the intake 1.5 m deep and the other located at a deep site with the intake about 5.1 m deep. Each pump was operated at flows of 3.4^3/min (2 cfs) and 5.5 m^3/min (3 cfs) during May through August. About 12 times more larval fish and 840 times more fish eggs were entrained by the system at the shallow site than at the deep site. The number of larvae entrained per unit volume of water was greater when the pumps were operated at the high rather than the low volume, but the differences were not statistically significant. The rate of entrainment increased rapidly and remained high during June and decreased to low levels during July and August. Some species of fish were more susceptible to entrainment than others. Of the larval fish present per unit volume of water, about 10% were entrained at the shallow site and 4% at the deep site.

Activity: water regulation/withdrawal/irrigation.

Impact: impingement or entrainment or entanglement.

Newbold, J.D., D.C. Erman, and K.B. Roby. 1980. Effects of logging on macroinvertebrates in streams with and without buffer strips. Can. J. Fish. Aquat. Sci. 37:1076-1085. (ADF&G, Habitat Library, #R3635.)

The impact of logging with and without buffer strip protection on stream macroinvertebrates was examined through comparisons of community structure in commercially logged and control watersheds throughout northern California. A nonparametric test of community dissimilarities within matched blocks of two control and one or two treated stations showed significant (P less than 0.05) logging effects on unprotected streams when Euclidean distance and mutual information were used as dissimilarity indices, but not when chord distance was used. Shannon diversity in unprotected streams was lower (P less than 0.01) than in control (unlogged) streams; densities of total macroinvertebrate fauna and of Chironomidae, <u>Baetis</u>, and <u>Nemoura</u> were higher in unprotected streams than in controls (P less than 0.05). Streams with narrow buffer strips (less than 30 m) showed significant effects by the Euclidean distance test, but diversity varied widely and was not significantly different from that in either unprotected or control streams. Macroinvertebrate communities in streams with wide buffers (greater than or equal to 30 m) could not be distinguished from those of controls by either Euclidean distance or diversity; however, diversity in wide-buffered streams was significantly greater than in streams without buffer strips, indicating effective protection from logging effects. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in turbidity or suspended sediments.

Noggle, C.C. 1978. Behavioral, physiological and lethal effects of suspended sediment on juvenile salmonids. M.S. Thesis, Univ. Washington, Seattle, WA. 87 pp. (ADF&G, Habitat Library, #B1163.)

Studies were conducted to assess the effects of suspended sediment, created by logging activity, upon juvenile steelhead (Salmo gardneri), chinook salmon (Oncorpynchus tshawytscha), and coho salmon (O. Kisutch), in a stream environment. Static bioassay tanks were used to determine points of 50% mortality (LC_{50}), changes in fill histology, and changes in blood physiology. Two experimental stream designs were used to relate sediment concentrations to avoidance behavior.

Results indicate seasonal changes in the tolerance of salmonids to suspended sediment. Bioassays conducted in summer produced LC_{50}s less that 1,500 mg/l, whereas autumn bioassays showed LC_{50}s revealed structural damage by suspended sediment. Blood chemistry showed elevated blood glucose levels at sublethal suspended sediment concentrations. Experiments conducted with a turbid artificial stream and clear tributary indicated a reluctance by the fish to leave their established territories. Studies conducted with a Y-shaped stream showed a preference for turbid water at medium concentrations and slight avoidance at high concentrations. (Author's abstract: modified)

Activity: clearing and tree harvest; draining; dredging; grading/plowing; grazing.

Impact: change in turbidity or suspended sediments.

Norris, L.A., H.W. Lorz, and S.V. Gregory. 1983. Forest chemicals. Vol. 9 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Series: 1979-. USDA: Forest Service. Pacific Northwest Forest and Range Experiment Station, Portland, OR. Gen. Tech. Rept. PNW-149. 95 pp. (ADF&G, Habitat Library, #B2439.)

Herbicides, insecticides, fertilizers, and fire retardants are chemicals used to protect or enhance certain forest resources. Their use may directly affect anadromous fish by exposing them to toxic amounts of the chemical in water, food, or sediment. The potential for direct effects can be estimated, based on knowledge of the toxicity characteristics of the chemical and its movement, persistence, and fate in the environment. Indirect effects are also possible through chemically induced alteration of habitat, including direct effects on fish-food organisms. Indirect effects are manifested through chemically induced changes in the density and species composition of aquatic and terrestrial plants and insects. These effects may include alteration of nutrient, sediment, and temperature characteristics of the water, and changes in cover, food, or some other environmental characteristic that is important to the well-being of anadromous fish. These changes have not been as thoroughly studied as the direct effects but may be the most likely to occur.

The most important process by which chemicals enter steams is direct application, but drift from nearby treatment areas or units is also important. Mobilization of residues in short-lived stream channels during the first storms after application is sometimes important. All three processes can be influenced by forest managers. Selection and orientation of spray units to avoid streams and attention to the details of application to avoid drift will minimize chemical entry into streams and thereby reduce the likelihood of direct toxic effects on stream organisms.

Data on the movement, persistence, and toxicity of chemicals provide a basis for evaluating potential direct effects of chemical use on fish and fish-food organisms. Data are included for seven herbicides (2,4-D, picloram, atrazine, MSMA, fosamine ammonium, glyphosate, and dinoseb), five insecticides (Malathion, carbaryl, azinphos-methyl, carbofuran, and acephate), urea fertilizer, and the ammonium-based fire retardants. Comparison of exposures and toxicities of these materials shows their current uses provide a reasonable margin of safety to anadromous fish if direct application to surface waters is avoided.

The margin of safety (no-effect level/exposure level) is a good index to the probability that the use of a specific forest chemical will result in direct effects on anadromous fish. The larger the margin of safety, the less likely direct effects will occur. Margins of safety of less than one indicate direct effects are likely to occur. Calculations of margins of safety for fish of 14 chemicals are included in the report.

Activity: chemical application.

Impact: change in water temperature; addition of substrate materials; alteration of natural cover - riparian vegetation; change in levels of biocides; change in levels of nutrients.

Norton, M.G., and F. L. Franklin. 1980. Research into toxicity evaluation and control criteria of oil dispersants. Fish. Res. Tech. Rept. No. 57. Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research, Lowestoft, England. 20 pp. (ADF&G, Habitat Library, #B6221.)

The relative toxicity of a variety of types of dispersants was evaluated in two types of test situations, at sea and along beaches. In the sea test, the relative toxicities of several oils dispersed by physical means or by use of the four selected reference dispersants appeared to be unchanged over a range of different conditions (change in mixing energy, type of oil, concentration of oil and dispersant, and the disperant-to-oil ratio). The performance of a dispersant as judged by a pass/fail standard is, however, dependent on some of these variables. It is therefore necessary to adhere to the standard test conditions stipulated for licensing purposes.

The beach test is not senstive to the type or quantity of oil used, but the rate of application of the dispersants appears to affect the number of disperants passing the test. Thus it is necessary to maintain standard test conditions for licensing purposes.

A number of experiments have shown that the toxicity of oil to shrimps in the sea test is probably related to the effects of dispersed oil, rather than to chemical poisoning by dissolved oil components. The lack of information on the physico-chemical properties of chemically dispersed oil in relation to toxicity precludes an explanation of some of the effects measured. In general however, fine dispersions of oil were found to be the most toxic. Results of beach tests suggest that physical processes account for the toxicity of oil to limpets. (Author's conclusions)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Norton, S.E., A.S. Timbol, and J.D. Parrish. 1978. Effect of channelization on the distribution and abundance of fauna in selected streams. Part B in S.J. Timbol and J.A. Maciolek, eds. Effect of stream channelization on the distribution and abundance of fauna in selected streams. USFWS Biol. Ser. Prog. FWS/OBS-78/17. (ADF&G, Habitat Library, #B1221.)

Water temperature, pH, and donductivity were measured in channelized and unchannelized streams in Hawaii. The aquatic community structure was evaluated and full-scale monitoring was done for 20 mo, from February 1976 through September 1977. The channelized streams were found to have higher mean values and wider ranges of water temperature, pH, and conductivity than the unaltered study stream. Channel sections with concrete bottoms had higher values than natural bottom channels. Native fishes were reduced in heavily channelized streams, and species diversity was lower in channels with artificial bottoms. Channels with natural bottoms appear to be less damaging. Artifocial bottom channels with a wide, flat bottom were more detrimental than those with a narrower notch in the bottom, which provided a deeper, more natural flow. (Author's abstract: modified)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in levels of pH, alkalinity, or hardness.

Norton, M.G., R.A. Eagle., R.S. Nunny, M.S. Rolfe, P.A. Hardiman, and B.L. Hampson. 1981. The field assessment of effects of dumping wastes at sea: 8. Sewage sludge dumping in the outer Thames Estuary. Fish. Res. Tech. Rept. No. 62. Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research, Lowestoft, England. 62 pp. (ADF&G, Habitat Library, #B6224.)

Surveys of the outer Thames Estuary sewage sludge dumping ground in 1976-1978 have allowed the natural dispersive processes of the area to be described and the effects of dumping on water quality, sediment composition, and the benthos of the area to be determined.

The surveys of water quality showed that the main effect of dumping was an increase in the metal concentration of suspended particles near the dumping ground, although increased concentrations of dissolved zinc and cadmium also resulted. Detectable elevations due to dumping activities were largely restricted to the Barrow Deep, whereas those observed inshore towards the River Thames appeared to be due to river outflow. The dissolved metal concentrations found in waters affected by river inputs were in proportion to the estimates of the quantities of metal entering the estuary from that source.

The good dispersive characteristics of the area have thus prevented the occurrence of seriously detrimental accumulations of metals and organic substances. However, it appears that current rates of dumping have somewhat exceeded the dispersive capacity of the area, resulting in readily identifiable areas where organic matter and metals have accumulated. These have placed the natural fauna under stress and promoted the growth of pollution indicator species. These changes are limited to a relatively small area and are not significant for commercial fisheries, but they do suggest that further increases in dumping may lead to more widespread, significant, and readily-identifiable effects. (Author's conclusions; partial)

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; change in levels of heavy metals.

Nunnally, N.R. 1978. Stream renovation: an alternative to channelization. Environ. Manage. 2(5):403-411. (ADF&G, Habitat Library, #R5105.)

Channelization is one of the most common solutions to urban drainage problems, despite the fact that channelized streams are frequently morphologically unstable, biologically unproductive, and aesthetically displeasing. There is increasing empirical and theoretical evidence to suggest that channelization may be counterproductive unless channels are designed to prevent the bank erosion and channel silting that often accompanies stream dredging. Many of the detrimental effects of channelization can be avoided, with little compromise in channel efficiency, by employing channel design guidelines that do not destroy the hydraulic and morphologic equilibria that natural streams possess. The guidelines include minimal straightening; promoting bank stability by leaving trees, minimizing channel reshaping, and employing bank stabilization techniques; and emulating the morphology of natural stream channels. This approach, called stream restoration or stream renovation, is being successfully employed to reduce flooding and control erosion and sedimentation problems on streams in Charlotte, North Carolina. (Author's abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

O'Clair, C.E. 1983. Effect of bark deposition at log transfer facilities on populations of Dungeness crabs and clams. Executive Summary, NWAFC, Auke Bay Laboratory. Watershed and Estuarine Ecosystem Project. (ADF&G, Habitat Library, #R3911.)

This study compared populations of Dungeness crabs (Cancer magister) and clams (principally steamer clams Protothaca staminea and butter clams Saxidomus giganteus) at Log Transfer Facilities (LTFs) with those at nearby control sites in six bays in southeastern Alaska. Dissolved oxygen, pH, oxidation-reduction potential, and concentrations of toxic products of decomposition (ammonia and hydrogen sulfide) in the water column-30 cm above the bark-water interface were not significantly different at LTF than at control sites. However, levels of sulfide and ammonia in the interstitial water of deposits of bark at LTFs were significantly higher than those in the pore water in-sediments at the control sites. Dungeness crabs were rarely observed by divers at LTFs and were seen burrowed into the bark at only one LTF. Crabs at this site were burrowed into sediments at the periphery of the bark deposit and were observed walking over the surface of the bark. These crabs were in poor physical condition, showing shell erosion disease, necrosis of the antennal gland, and severe lesions in the antennal gland, gill, midgut, and hind gut. Crabs at this site also had significantly more missing leg segments than did control crabs. Clam densities were lower in areas covered with bark than at control sties. There was a 50% reduction in clam densities at active and recently inactive LTFs and a 30% reduction at past inactive LTFs, as compared with control sites.

Activity: log storage/transport.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in levels of other toxic compounds - bark or log leachates.

O'Clair, C.E., and S.D. Rice. 1985. Depression of feeding and growth rates of the seastar _Evasterias troschelii_ during long-term exposure to the water-soluble fraction of crude oil. Mar. Biol. 84:331-340(1985). (ADF&G, Habitat Library, #R3694.)

To test the effect of petroleum hydrocarbons on predation by the seastar _Evasterias troschelii_ on the mussell _Mytilus edulis_ (L.), the authors exposed the predator with the prey to six concentrations of the water-soluble fraction (WSF) of Cook Inlet crude oil. Seastars and mussels were collected at Auke Bay, Alaska, in November 1980. During a 28-d exposure in a flow-through system. Seastars were more sensitive to the WSF than mussels: the LC_{50} for the seastars was 0.82 ppm at day 19 and, although no mussels were exposed to WSF for more than 12 d, none died. Daily feeding rates (whether in terms of number of mussels/seastar/d or dry weight of mussels/seastar/d) were significantly reduced at all concentrations above 0.12 ppm. At 0.20, 0.28, and 0.72 ppm WSF, daily feeding rates (in terms of dry weight of mussels) were, respectively, 53, 37, and 5% of the control rate; at the two highest concentrations (0.97 and 1.31 ppm WSF), the seastars did not feed. Seastars at concentrations greater than 0.12 ppm WSF grew sower than individuals from the control group and the 0.12 ppm-treatment group combined. These laboratory results show than _E. troschelii_ is more sensitrive to chronic low levels of the WSF of crude oil. The possibility that such oil pollution could reduce predation and permit _M. edulis_ to monopolize the low intertidal zone of southern Alaska remains to be studied. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

O'Connor, J.M., D.A. Neumann, and J.A. Sherk, Jr. 1976. Lethal effects of suspended sediments on estuarine fish. U.S. Corps of Engineers, Coastal Engineering Research Center, Tech. Pap. No. 76-20. 38 pp. (ADF&G, Habitat Library, #R1382.)

A-3 yr laboratory study identified certain estuarine fish sensitive to the effects of particle size and concentration of a) suspended mineral solids similar in size to sediment likely to be found in estuarine systems in concentrations typically found during flooding, dredging, and disposal of dredged material and b) natural sediments in identical experiments.

Significant mortality of estuarine fish was demonstrated at each of three suspended mineral solid concentrations. Estuarine fish were classified, using static bioassays as follows: tolerant (24-h LC_{10} greater than or equal to 10 g/l), sensitive (10 g/l greater than 24 h LC_{10} greater than 1.0 g/l), or highly sensitive (24 hr LC_{10} less than or equal to 1.0 g/l) to fuller's earth (Fisher F-90, technical grade) suspensions.

Generally, bottom-dwelling fish species were most tolerant to suspended solids; filter feeders were most sensitive. Early life stages were more sensitive to suspended solids than adults; filter feeders were most sensitive. Bioassays with natural sediments indicated that suspensions of natural muds affected fish in the same way as fuller's earth, but higher concentrations of natural material were required to produce the same level of response.

The effect of finely divided solids on fish was dependent on the concentration, particle-size distribution, and angularity of the suspended particles. The cause of death was the same in all experiments--anoxia.

None of the fish species tested in these experiments occur in Alaskan waters. This paper is, however, one of a very few dealing with sediment impacts on estuarine fish species. Application of these results should be applied with caution to Alaskan fish species of similar feeding behavior. (Author's abstract: modified)

Activity: clearing and tree harvest; draining; dredging; grading/plowing; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

O'Connor, J.M., D.A. Neumann, and J.A. Sherk. 1977. Sublethal effects of suspended sediments on estaurine fish. U.S. Army, Corps of Engineers, Coastal Engineering Research Center. Tech. Paper No. 77-3. 90 pp. (ADF&G, Habitat Library, #B2151.)

This experiment was designed to test the biologically significant sublethal effects of suspended solids on estuarine fish. The range of sediment concentrations used in these experiments is similar to that found in estuarines during storms, flooding, dredging, and dredged-material disposal. The experimental suspensions induced stress responses in several species of fish.

Exposure to sediment suspensions increased the hematological parameters measured in white perch, hogchoker, mummichog, and striped killifish, in response to suspended solids interference with oxygen-carbon dioxide transport at the gill. The gill tissue of white perch became covered with mucus and the respiratory surface area was reduced in the five-day test. Hogchokers showed high rates of liver glycogen depletion during times of sediment stress, indicating carbohydrate utilization and drainage of metabolic reserves. Sediment suspensions reduced the oxygen consumption rates of striped bass and white perch, which interfered with the respiration of the fish.

The authors concluded that stress from suspended sediments may cause changes in growth, survival, and reproduction of fish. The effects of suspended particles on fish depend on the concentration and composition of the particles and the stress tolerance of the fish species. In addition, the authors note that effects of suspended particles may be by complicating factors such as sorbed toxic metals, pesticides, high BOD, and high nutrient content of the medium.

Activity: clearing and tree harvest; dredging; grading/plowing; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

O'Rear, C.W. 1975. The effects of stream channelization on the distribution of nutrients and metals. Water Resour. Res. Inst., Univ. North Carolina, Greenville. 52 pp. (ADF&G, Habitat Library, #B6558.)

The project was designed to determine the distribution patterns of nutrients and metals in channelized and unchannelized stream segments and to determine if modifications occur in the distribution of nutrients. Adjacent segments of Swift Creek, Pitt County, North Carolina, were used as the sites. An upstream segment channelized in 1937 was used as a representative natural stream, while a segment approximately 1 km downstream, channelized in 1965, was used as a representative channelized stream. Sampling was performed from September 1973 through November 1974.

Water temperatures in the natural segment tended to be lower than in the channelized segment due to a greater canopy cover in the natural segment. Dissolved oxygen in the channelized segment was consistently higher during low-flow periods, with average differences exceeding 2 mg/l.

Most of the nitrogen and phosphorus moved through both stream segments during the high-flow periods. The highest concentrations were observed during the low-flow period of October through December. Ammonia-N accounted for most of the increased nitrogen concentrations, while particulate phosphorus accounted for the rise in total phosphorus. Nutrient concentrations in Chicod Creek were lower than the unchannelized segment of Swift Creek. Modification of the nutrient distribution patterns could not be directly determined from the measured nutrient concentrations and flows. Dissolved metal concentrations between the two segments showed no significant differences. (Author's abstract)

Activity: channelizing waterways.

Impact: change in water temperature; change in level of dissolved oxygen, nitrogen; change in levels of heavy metals; change in levels of nutrients.

Olla, B.L., and A.J. Bejda. 1983. Effects of oiled sediment on the burrowing behavior of the hard clam, _Mercenaria mercenaria_. Mar. Environ. Res. 9:183-193. (ADF&G, Habitat Library, #R3910.)

The burrowing behavior of juvenile hard clams, _Mercenaria mercenaria_, in oil-contaminated (Prudhoe Bay crude oil) sediment was examined in a series of laboratory experiments. At oil concentrations within the range that might occur after an oil spill, depth and rate of burrowing were altered. The depth to which clams in oiled sediment burrowed after 96 h was significantly shallower than the depth in the controls, whereas the time taken to burrow beneath the surface was longer in oil-contaminated sediment. Alterations in burrowing were indicative of avoidance behavior rather than of oil-induced debilitation. The results suggest that such alterations may increase the vulnerability of this species to predation.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Olsen, K. 1971. Influence of vessel noise on behavior of herring. Pages 292-294 in H. Kristjonsson, ed. Modern fishing gear of the world. Fishing News Books Ltd. 537 pp. (ADF&G, Habitat Library, #R3909.)

Olsen discussed the abilities of fish to detect sound and reports that cod (*Gadus morhua*) hear sound in the frequency range of 40 to 400 Hz and that herring (*Clupea harengus*) detect sound between 20 and 10,000 Hz. Directional hearing has been demonstrated in shark, cod, and schools of herring. In behavioral experiments on herring, small schools of herring showed strong nervous reactions to various noise signals. Interrupted or pulsed signals scared the schools more than continuous signals, and low-frequency noise scared the schools more than noise of a higher frequency. Olsen cited examples from the tactics used by the capelin purse seine fishery in Norway to show that seasonal or daily changes in the behavior of fish may make them more susceptible to noise levels. In the spawning season, capelin seem insensitive to any noise level changes, but during the feeding period the behavior is very changeable in response to noise. In addition, laboratory experiments showed that the rate of change of noise level gave significant behavioral differences; a quick increase in signal level gave earlier and more spontaneous reactions, and with a slow increase in signal an adaption seemed to occur.

Activity: human disturbance; transport of oil/gas/water - water; transport personnel/equipment/material - water.

Impact: increase in hydrostatic pressure or noise.

Ordzie, C.J., and G.C. Garofalo. 1981. Lethal and sublethal effects of short term acute doses of Kuwait crude oil and a dispersant Corexit 9527 on bay scallops, _Argopecten irradians_ (Lamark) and two predators at different temperatures. Mar. Environ. Res. 5:195-210. (ADF&G, Habitat Library, #R3908.)

Investigations of short-term acute exposure of bay scallops (_Argopecten irradians_) and two scallop predators, the oyster drill (_Urosalpinx cinerea_) and the common starfish (_Asterias forbesi_), to oil, dispersant, and oil-dispersant mixtures (Kuwait Crude Oil and Corexit 9527) suggested that predator and prey have different lethal susceptibilities. Scallops were most sensitive to dispersant and dispersant mixed with oil; starfish were sensitive to only dispersant, while the oyster drill seemed unaffected even though all were exposed to dilutions of identically prepared stock solutions. Scallops were least susceptible during winter months and most susceptible at summer temperatures. Treatment had less effect on predators than on scallops at summer temperatures. Sublethal concentrations of dispersant and oil-dispersant mixtures diminished the behavioural ability of scallops to recognize drills and starfish. The degree of effect increased with temperature. Predator detection of prey at the same concentrations was more complex. The feeding response or posturing reflex of starfish was significantly slowed by all treatments. In contrast, drills were unaffected in their recognition of scallop effluent in a choice chamber after treatment.

The authors point out that in light of the differential susceptibility demonstrated in their experiments, the concept of an indicator species is difficult to defend. The authors also emphasize the importance of testing susceptibilities of animals in different seasons.

Activity: drilling; processing oil/gas; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Oregon State Game Commission, Oregon State Sanitary Authority, and U.S. Public Health Service. 1955. Gold dredge siltation, Powder River, Oregon, 1953-1955. 10 pp. (ADF&G, Habitat Library, #R2849.)

Data collected during active operation of a bucket-type dredge in the Powder River Valley, near Sumpter, Oregon, from 1953-1955 is summarized. Impacts of siltation on endemic and introduced rainbow trout populations, and macroinvertebrates are discussed.

Measurements of turbidity ranged from 600 to 3,000 ppm during dredge operations in the months of February through October, 1954. Measurements reduced to between 25 to 100 ppm immediately following cessation of dredging.

Populations of rainbow trout and whitefish were indentified by electrofishing in tributary streams during active dredging. These fish were not found below the dredge for a distance of 50 mi. Other fish species are reported to have been captured below the dredge (squaw fish, suckers, shiners, and chiselmouth); however, interpretation is not possible because the paper does not identify these species by Latin name.

Eyed rainbow trout eggs and developed fingerlings were introduced in a controlled experiment. All eggs were destroyed over a 6-d period; fingerling mortality reached 57% within 20 d.

Once dredging ceased, rotenone was used to eliminate species which had thrived during increased levels of turbidity (those species listed above). Rainbow trout were successfully reintroduced following dredging.

A decrease in available food organisms during dredging is cited, as are the recovery of these populations following active dredging. As with fish species, reference is only made to common names of macroinvertebrate species.

Activity: dredging; grading/plowing.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Oregon Wildlife Commission. 1974. Federal aid progress report fisheries: immediate effects of logging on the freshwater environment of salmonids. Oregon Wildlife Commission, Portland, OR. Proj. AFS-58 final rept. 101 pp. (ADF&G, Habitat Library, #B1451.)

Twelve small, coastal western Oregon streams were studied in the summers of 1967-1972 to assess the effects of several types of logging practices. Streams were studied one season prior to logging and one season after logging. Three general methods of logging were employed: clear-cutting without buffer strips, clear-cutting with buffer strips, and road construction with partial thinning. All streams contained coho salmon (Oncorhynchus kisutch) and/or cutthroat trout (Salmo clarki). Steelhead trout (S. gairdneri) were present in four streams. Parameters measured included population estimates, condition factors, biomass, water temperature, surface and intragravel dissolved oxygen, streamflow, gravel composition, pH, and pool/riffle and spawning gravel estimates.

Cutthroat trout populations declined following logging, while coho salmon populations were apparently little affected. The maximums and the ranges of temperatures increased in 10 of the streams. Minimum recorded intragravel and surface dissolved oxygen levels declined on the majority of streams. Gravel was less evenly distributed and composition was more variable in streams following logging. Streams with intact buffer strips suffered less gravel disruption. Streambed damage varied greatly among streams and was generally related to the type of logging and the care taken by individual operators in yarding, falling, and road construction. The short-term approach used in this study is useful for spot analysis of physical and biological parameters. However, use of a long-term, case history approach is a more valid technique in the ultimate interpretation of results.

Activity: clearing and tree harvest; grading/plowing; log storage/transport; stream crossing - fords; stream crossing - structures.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen.

Orrell, R.F., and R.C. Johnson. 1975. Fish gap study, Swinomish Channel jetty, 1974. Wash. Dep. Fish., Div. Res. (ADF&G, Habitat Library, #R3821.)

This study was conducted to determine if juvenile salmon will successfully use two fish passage gaps in the Swinomish Channel jetty, Skagit Bay, Washington. Visual observations were made from vantage points approximately 10 ft above the water surface. Juvenile salmon were enumerated as they passed through the two gaps, along the north and south shores of the jetty and around the outside end of the jetty. The study period extended from 17 April to 12 June 1974. Results indicated that juvenile salmon did utilize the fish gaps to reach important rearing areas in the Swinomish Channel. However, sedimentation occurred within the fish gaps and was observed to cause reduced accessibility to the rearing areas.

Activity: filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Osborn, J.G. 1980. Effects of logging on resident and searun populations of cutthroat trout (Salmo clarki) in small tributaries of the Clearwater River, Jefferson County, Washington, 1978-1979. Fisheries Research Institute, Univ. Washington, Seattle. FRI-UW-8018. 56 pp. (ADF&G, Habitat Library, #B1170.)

Five streams were chosen for a study of the effects of logging on resident and sea-run cutthroat trout. The two resident cutthroat trout streams, one logged and the other in its natural state, were studied intensively with a short-term perspective (2-yr period), and the three logged sea-run and resident cutthroat trout streams were studied extensively with a long term perspective (recovery of up to 18 yr). The populations of trout in the logged resident cutthroat streams were determined to have maintained their abundance and age distribution over the course of the study, in spite of logging operations in and across the stream channels. Stream morphology and organic debris providing in-stream fish habitat had been considerably reduced due to logging. This may have long-term deleterious effects on the trout population.

The extensive study showed that with proper logging techniques, streams can support abundant numbers of trout after being logged. The substrate and organic debris sources were not significantly disrupted during yarding operations and, therefore, provided stable habitat which is conducive to good fish production. (Author's abstract)

Activity: clearing and tree harvest.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Otte, G., and C.D. Levings. 1975. Distribution of macroinvertebrate communities on a mud flat influenced by sewage, Fraser River estuary, British Columbia. Fish. Mar. Serv. Res. Dev. Tech. Rept. 476. 88 pp. (ADF&G, Habitat Library, #B1146.)

The distribution of the benthic macrofauna was studied from May to November 1974 on an estaurine mud flat receiving sewage from the city of Vancouver, British Columbia. The benthic communities in the muddy, upper areas of the tidal flats are more resistant to sewage input, whereas benthos in the lower, sandy zone are more severly disrupted. At a distance from the outfall, a large increase in number of individuals and biomass was observed as well as an increase in the number of species. Benthic communities in a dredged channel, which receives the sewage at low tide, showed an increase in the number of species and a decrease in density with increasing distance from the outfall.

In the area adjacent to the outfall, environmental conditions such as salinity, temperature, pH, and dissolved oxygen were apparently limiting the distribution of the benthic organisms. Continuous measurements of dissolved oxygen one centimeter above the bottom, which is the most important water layer for the benthos, showed that the oxygen content can fall to zero. At high tide, sea water rich in oxygen enters the area and the oxygen is rapidly consumed by the oxygen demand of the sediments. (Author's abstract: modified)

Activity: sewage disposal.

Impact: change in water temperature; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness; change in level of salinity.

Pacific Northwest Pollution Control Council. 1971. Log storage and rafting in public waters. A task force report approved by P.N.P.C.C. Unpubl. document. 56 pp. (ADF&G, Habitat Library, #B6129.)

Available research findings show that log debris, bark, and wood leachates resulting from log handling in public waters can adversely affect water quality. The range of effects varies from mild to gross depending upon the specific characteristics of both the involved water body and log-handling practices. In most instances where logs depreciate water quality, there are a number of practicable changes that can be made to improve conditions.

This report sets forth a number of recommendations for implementing improved log handling practices that will benefit water quality:

1. Log storage and handling should be restricted in or eliminated from public waters where water quality standards cannot be met at all times or where these activities are a hindrance to other beneficial water uses such as small craft navigation.
2. The free-fall, violent dumping of logs into water should be prohibeted since this is the major cause and point source of loose bark and other log debris.
3. Easy let-down devices should be employed for placing logs in the water, thereby reducing bark separation and the generation of other wood debris.
4. Positive bark and wood debris controls, collection, and disposal methods should be employed at log dumps, raft building areas, and mill-side handling zones. This would be required for both floating and sinking particals.
5. Log dumps should not be located in rapidly flowing waters or other water zones where positive bark and debris controls cannot be made effective.
6. Accumulations of bark and other debris on the land and docks around dump sites should be kept out of the water.
7. Whenever possible, logs should not be dumped, stored, or rafted where grounding will occur.
8. Where water depths will permit the floating of bundled logs, they should be secured in bundles on land before being placed in the water. Bundles should not be broken again except on land or at millside.
9. The inventory of logs in public waters for any purpose should be kept to the lowest possible number for the shortest possible time.
10. Industry should provide and periodically update an accurate quantification of its use of public waters for log handling activities. (Author's summary)

Activity: log storage/transport.

Impact: physical disturbance of substrate materials; change in levels of other toxic compounds - bark or log leachates.

Parker, R.R., and J. Sibert. 1973. Effect of pulpmill effluent on dissolved oxygen in a stratified estuary - I. Empirical observations. Water Res. 7:503-514. (ADF&G, Habitat Library, #R5140.)

Pulpmill effluent discharged at the surface in Alberni Inlet, British Columbia, is shown to prevent oxygen production in the stratum immediately beneath the halocline by restricting light penetration. This stratum is the source of marine water for entrainment in the halocline and to the upper mixed zone. This situation cannot be remedied by removal of BOD from the pulpmill effluent; rather, the staining properties must be diminished or removed. (Authors' abstract)

Activity: processing lumber/kraft/pulp.

Impact: change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen.

Parrish, J.D., J.A. Maciolek, A.S. Timbol, C.B. Hathaway, Jr., and S.E. Norton. 1978. Stream channel modification in Hawaii. Part D: summary report. USDI: USFWS. FWS/OBS-78/19. 18 pp. (ADF&G, Habitat Library, #B6557.)

A 3-yr, statewide study was made of the occurrence and consequences of channelization in Hawaiian streams. The 366 perennial streams of the state were inventoried for the first time, and some basic information was catalogued on their physical characteristics, complete status of channel alteration, and macrofaunal communities. Fifteen percent of the state's streams have channels altered in at least one of six forms. There are 151 km of altered channel, 89% of which is on Oahu. Forty percent of the modified channel length is concrete lined - the form of alteration found to be most ecologically damaging.

Field measurements showed that channel alterations commonly caused large changes in environmental parameters. Whereas the average pH value in natural streams was 7.2, the yearly mean mid-afternoon pH in lined channels was as high as 9.9. Conductivity and dissolved oxygen were significantly increased. The range of daily temperatures in lined channels was 17.8-36.2°C as compared to 19.5-26.8°C in natural channels. The diel insolation cycle of exposed, artificial channels caused extreme diel change in all these environmental parameters. The native species tested in the laboratory had less tolerance of high temperatures than exotics, and some natives had upper lethal temperature limits within the temperature range measured in channelized streams.

Twenty-five species of fish and decapod crustaceans were collected statewide, of which only 8 were native. Native species were not abundant in most areas intensively surveyed; they appeared to thrive only in areas remote from development. Certain introduced species, notably poeciliid fishes, were abundant in the most heavily channelized sections, whereas native species were almost entirely absent.

Channelization in its various forms 1) increases turbidity, 2) destroys natural substrate habitat, 3) creates wide, shallow, unnatural flows, 4) causes excessive illumination, water temperatures, and pH levels, and 5) creates topographical difficulties for upstream migration. Effects 2) and 4) are believed to create especially serious problems for the native macrofauna that is benthic/demersal, cryptic, and obligately diadromous. As a result, present channelization practices appear to be damaging the quality of extensive stream habitat for native species and contributing to their replacement by hardy, useless exotics.

Mitigation should include 1) minimizing channelization projects, 2) maintaining the natural length of channels, 3) maintaining (replanting) the vegetative canopy, 4) maintaining natural bottom material wherever possible, 5) using intermittent sections of natural bottom between minimum sections where lined channel is unavoidable, 6) building a narrow, low-flow notch into the bottom of flat lined channels, 7) installing minimum length culverts in ways that will avoid downstream elevations above stream level (waterfalls). (Authors' summary)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness.

Patric, J.H., and G.M. Aubertin. 1977. Long-term effects of repeated logging on an Appalachian stream. J. For. 75(8): 492-494. (ADF&G, Habitat Library, #R3830.)

A watershed in an Appalachian experimental forest has been logged four times since the turn of the century. Little is known of how streams were affected by logging after 1901 and during World War II, but the effects of diameter-limit cutting in 1958 and 1972 are well documented. [Note: Tree harvest was selective for trees with trunk diameters exceeding 17 in.] Both cuts caused small increases in streamflow but had little effect on water quality by any criterion except turbidity, which was increased by poorly located and ill-managed logging roads. The evidence suggests that if responsible road practices are followed, continued diameter-limit cutting will not harm forest streams. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments.

Patric, J.H., and J.L. Gorman. 1978. Soil disturbance caused by skyline cable logging on steep slopes in West Virginia. J. Soil Water Conserv. 33(1):32-35. (ADF&G, Habitat Library, #R3849.)

A URUS mobile skyline system removed an average volume of 32.6 m^3 (4,500 board measure) per ha of hardwood logs from 16 ha of steep forest land in West Virginia. Six months after logging there was no evidence of reduced infiltration, increased bulk density, overland flow, or accelerated erosion, except on heavily used skid trails. The soil was severely disturbed on less than 3% of the logged land; more than 90% was undisturbed. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water; physical disturbance of substrate materials.

Pearson, R.G., and N.V. Jones. 1975. The effects of dredging operations on the benthic community of a chalk stream. Biol. Conserv. (8):273-278. (ADF&G, Habitat Library, #R2671.)

This work was carried out to examine the effects of drag-line operations on the benthic community of a gravel stretch of the River Hull, North Humberside, Great Britain. The study section of river was uniform in appearance with chalk chips up to 3 cm forming the substrate; water depth averaged 10 cm. Dredging involved the gravel layer, down to bedrock (approximately 30-40 cm).

Generally, the impact of dredging on benthic invertebrates were dramatic but short-term. There was a significant decrease in numbersof Oligochaeta that was attributed to dredging. Data collected from the drift showed that dredging caused a dramatic but transitory increase in activity, particularly among Chironomidae.

The authors conclude that drag-line operations produce mainly short-term effects on the benthic fauna. The behavior of the animals produces a rapid redistribution of the fauna. The time of year may also influence the magnitude of its effect; spring or early summer disturbance might have a shorter term effect than dredging in autumn or winter, as breeding of most species would take place shortly after redistribution in spring.

Activity: dredging.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

Pease, B.D. 1974. Effects of log dumping and rafting on the marine environment of Southeast Alaska. USDA: Forest Service Gen. Tech. Rept. PNW-22. 1974. 58 pp. (ADF&G, Habitat Library, #B5053.)

The extent of water-dependent log-handling and storage facilities in Southeast Alaska is summarized, along with the available literature on the environmental impact of these facilities. Field studies were conducted at 16 sites and correlated with laboratory studies of leaching rates and toxicity of the four major wood species harvested in Southeast Alaska. Significant effects on water quality are believed to occur only under unique conditions and were observed at only 2 of the 16 sites. Bark deposits with a high demand for oxygen were observed at all active and abandoned log-dumping sites. The abundance of benthic infauna was noticeable reduced in bark covered areas and intertidal raft storage areas. The laboratory studies demonstrated that oxygen-demanding organic compounds rapidly leach from logs in water but precipitate in salt water. The wood leachates are toxic to pink salmon fry in the laboratory but probably have little effect on fish in the natural environment. Further studies are needed to further quantify the environmental impact of water-oriented log-handling practices. (Author's abstract)

Activity: log storage/transport.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates.

Peddicord, R., and V. McFarland. 1976. Effects of suspended dredged material on the commercial crab, Cancer magister. Pages 633-644 in P.A. Krenkel, J. Harrison, and J.C. Burdick, eds. Proceedings of the specialty conference on dredging and its environmental effects. Mobile, AL. American Society of Civil Engineers, N.Y. 1,037 pp. (ADF&G, Habitat Library, #R3916.)

Juvenile Cancer magister 3-4 cm in carapace width were exposed for 25 d to suspensions of sediment from an industrialized shipyard area. Mortalities began with sediment concentrations of at least 9.2 g/l after 8 d and reached 38% after 25 d. Mortality was closely associated with molting, since over 92% of the deaths occurred during molting. Many crabs that survived molting showed physical abnormalities such as missing or deformed appendages. Serious abnormalities occurred from 1.8 to 4.3 g/l, which may be a reliable estimate of the concentrations of sediment likely to have a detrimental effect with prolonged exposure

The authors noted that previous research has shown that pipeline and hopper disposal operations can produce layers of fluid mud with suspended sediment concentrations exceeding those of their experiments. These concentrations may persist throughout the disposal operation. The authors concluded that these experiments showed that 1 to 3 wk exposure to concentrations of 2 g/l to 20 g/l of some harbor sediments must be considered lethal for juvenile Cancer magister.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Peddicord, R.K., and V.A. McFarland. 1978. Effects of suspended dredged material on aquatic animals. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Miss. Tech. Rept. D-78-29. 102 pp. (ADF&G, Habitat Library, #B5337.)

The purpose of this study was to determine the tolerance limits of a variety of adult and juvenile marine, estuarine, and freshwater fish and invertebrates to suspensions of relatively uncontaminated and contaminated harbor sediments. All species tested were able to survive exposure for much longer period and at higher concentrations of uncontaminated sediments than are created by typical dredging or disposal operations. Tissue accumulation of contaminants from suspensions of sediment was found in less than 25% of the cases.

Juvenile Dungeness crabs showed a greater sensitivity than other species to physical effects of mineral particles, and many crabs were killed or deformed during molting. Juvenile Dungeness crabs could also be killed if covered by contaminated fluid mud. It was not determined if Dungeness crabs could have moved fast enough to escape the fluid mud. Shrimp (Crangon spp.) and lobsters tested were relatively unaffected by sediment suspensions molted normally during the tests.

Activity: dredging; drilling; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in levels of heavy metals; change in levels of chlorinated compounds.

Pequegnat, W.E., D.D. Smith, R.M. Darnell, B.J. Presley, and R.O. Reid. 1978. An assessment of the potential impact of dredged material disposal in the open ocean. U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss. Tech. Rept. D-78-2. 642 pp. (ADF&G, Habitat Library, #B6560.)

This report contains an evaulation of <u>potential</u> physical, chemical, and biological impacts that may occur from the disposal of dredged material in the deep ocean at or beyond the outer ridge of the continental shelf of United States coastal waters. However, it also provides a valuable review of <u>documented</u> impacts literature regarding the effects of disposal on marine biota.

The main body of the report is composed of two multipart sections: Section A, Deep Ocean Disposal Perspectives, and Section B, Deep Ocean Disposal Environemtnal Considerations. The three major parts of Section A are 1) the basis for and objectives of the study, together with an overall evaluation of the need for and impacts of deep ocean disposal of dredged material; 2) a discussion of the dredging-disposal process and the nature of dredged materials; and 3) the actual designation of favorable and poor deep-ocean areas for disposal of dredged material, as well as the criteria upon which each selection was based. Emphasis is placed upon the need for utilization of ocenaographic information in the selection of disposal sites within these areas and the belief that effective management of the use of deep-ocean sites will require a basic understanding of marine ecological systems. These units are followed by a set of conclusions and a summary of the principal finds. In brief, it is concluded that deep-ocean disposal of dredged material can be carried out without appreciable damage to any aspect of the marine environment. Section B is devoted to 1) a discussion of the workings of marine ecological systems, 2) the essential oceanographic conditions existing off the coasts of all geographic sectiors of the United States and its possessions, and 3) an analysis of the fate of dredged material disposed in the deep ocean and the potential impacts that it may generate. Thus, this section of the report was designed to provide the managers of disposal sites in the Corps of Engineers with a working know-ledge of the marine environment and its functions in their districts in order to facilitate effective selection and use of disposal sites.

Activity: solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in levels of heavy metals; change in levels of hydrocarbons.

Percy, J.A. 1976. Responses of arctic marine benthic crustaceans to sediments contaminated with crude oil. Environ. Pollut. 13:1-10. (ADF&G, Habitat Library, #R1432.)

The responses of several arctic marine benthic crustaceans to sediments experimentally contaminated with crude oils were examined. The amphipod Onisimus affinis overwhelmingly selected clean rather than oil-contaminated sediments. The response was most pronounced at low oil concentrations, and the ability to discriminate was abolished at the highest concentrations tested. Weathering of the oiled sediment for 1 wk reduced the avoidance response. Another amphipod and two isopod species tested did not discriminate consistently between oiled and clean sediments. Potential ecological consequences of these behavioral responses are discussed. (Author's abstract: modified)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Perttila, M., V. Tervo, and R. Parmanne. 1982. Heavy metals in Baltic herring and cod. Mar. Pollut. Bull. 13(1):391-393. (ADF&G, Habitat Library, #R3907.)

This paper mainly deals with measurements of heavy metal concentrations in species of fish in different areas. The authors found that in the Baltic Sea area the mean values of trace metal contents in herring muscle do not differ significantly from one another in different areas. Cod, however, exhibits areal differences, which, with the exception of lead, follow the areal differences of metal concentrations in sea water. The authors concluded that these areal differences suggest that, in spite of the extensive migration of cod, it is a better indicator species for aquatic pollution than is herring. Cod feeds mainly on herring and benthic animals, and thus harmful substances are accumulated to higher concentrations in cod than in herring.

Activity: dredging; processing minerals; solid waste disposal.

Impact: change in levels of heavy metals.

Peters, J.C., and W. Alvord. 1964. Man-made channel alterations-in thirteen Montana streams and rivers. Trans. N. Am. Wildl. Nat. Res. Conf. 29:93-102. (ADF&G, Habitat Library, #R5122.)

There were 1,987 individual alterations in the 768 mi of stream channel inventoried. As a result of the man-made alterations, the length of the channels was shortened by 68 mi. Agricultural activities accounted for the greatest length of channel altered followed in order by railroad construction, road construction, and urban and industrial development. Relocated channels accounted for the greatest length of channel altered followed in order by riprapping, diking, and channel clearance. Comparing the total weight of all fish in the natural channels to that of altered channels indicated that, 1) the total weight of all fish species was more than 5.5 times greater, 2) the total weight of the trout and whitefish combinded was over 9 times greater in the natural channels, and 3) in each stream there was a greater total weight of fish in the natural channels.

Activity: channelizing waterways; filling (aquatic and wetland habitats); grading/plowing; stream crossing - structures.

Impact: change in depth or velocity of water.

Peters, G.B., H.J. Dawson, B.F. Hrutfiord, and R.R. Whitney. 1976. Aqueous leachate from western red cedar: effects on some aquatic organisms. J. Fish. Res. Bd. Can. 33:2703-2709. (ADF&G, Habitat Library, #R3575.)

Water-soluble extractives from western red cedar heartwood, bark, and foliage were investigated for their toxicity to aquatic organisms. The heartwood lignans and bark extractives were found to be moderately toxic, but the foliage terpenes and heartwood tropolones were more toxic, causing 50% mortality to coho salmon (Oncorhynchus kisutch) fry at 0.33 and 2.7 mg/l, respectively. Tropolones were significantly less toxic to invertebrates than to free-swimming stages of the fish tested. Fry were found to be the stage of development of coho salmon most sensitive to the tropolones, and eyed eggs the least sensitive. Sensitivity of the coho fry to tropolones was moderated by previous sublethal exposure or the presence of a chelatable cation. Results from field studies and a leaching study indicate that directly releasing cedar leachate from landfills or allowing logging debris to enter streams should be avoided. (Authors Abstract).

Activity: clearing and tree harvest; log storage/transport; processing lumber/kraft/pulp.

Impact: change in levels of other toxic compounds - bark or log leachates.

Peterson, R.H., and J.L. Metcalfe. 1981. Emergence of Atlantic salmon fry from gravels of varying composition: a laboratory study. Can. Tech. Rept. Fish. Aquat. Sci. 1020. 15 pp. (ADF&G, Habitat Library, #B1576.)

Atlantic salmon eggs were incubated in various gravel and sand mixtures with various water flows and two directions of water current. Fine sand (0.06-0.5 mm) was more effective than coarse sand (0.5-2.2 mm) in reducing numbers of emergent fry. The number of fry emerging was related to the formula $S_f/8 + S_c/16$, where S_f = proportion of fine sand and S_c porportion of coarse sand in the gravel mixutre. Emergence was not affected by reduction of water supply to the eggs. Strong upwelling water currents mitigated the effects of sand to some degree. Upwelling water currents also induced earlier fry emergence. There was a tendency for smaller fry to emerge later. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: addition of substrate materials.

Phillips, R.W. 1971. Effects of sediment on the gravel environment and fish production. Pages 64-74 in J. Morris, ed. Proceedings of a symposium on forest land uses and stream environment. Oregon State Univ., Corvallis. (ADF&G, Habitat Library, #R2953.)

Research in the field is summarized. Sediment influences fish in several ways. In suspension, 1) it blocks the transmission of light, reducing algae production, and 2) it damages the gill membranes, causing death where concentrations are high and exposure is prolonged. When sediment settles on the gravel beds, it is harmful in the following ways: 1) It fills the interstices, reducing interchange between surface waters and waters within the gravel bed. This reduces the supply of dissolved oxygen to the egg, and interferes with the removal of metabolites (carbon dioxide and ammonia). 2) Sediment also forms a barrier to fry emergence by blocking the route of egress. 3) Low dissolved oxygen and the physical barrier effect of sediment appear to be additive in reducing survival. 4) Survival after fry emergence is impaired because of a loss of escape cover and a reduction of aquatic organisms that are food for fish. Examples are cited showing that pink and chum salmon survival is inversely related to the amount of sediment in gravel beds.

Activity: channelizing waterways; clearing and tree harvest; dredging; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Phillips, R.W., R.L. Lantz, E.W. Claire, and J.R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Tran. Am. Fish. Soc. 104(3):461-466. (ADF&G, Habitat Library, #R2955.)

Eight mixtures of sand and gravel were tested in experimental troughs, to simulate hatching conditions in coho salmon and steelhead trout redds. Fry were released into perforated, open-ended chambers below the gravel surface. An inverse relationship was found between the quantity of fines and survival to emergence. Mean survival to emergence for coho salmon ranged from 96% in control mixture to 8% in 70% sand (less than 3.3 mm diameter). Mean survival to emergence for steelhead ranged from 94 to 18%, respectively. Premature emergence of coho fry was related to higher concentrations of fines. These premature fry were smaller and retained more yolk than fry emerging at normal times. (Author's abstract: modified)

Activity: channelizing waterways; clearing and tree harvest; dredging; grading/plowing; processing minerals.

Impact: addition of substrate materials.

Platts, W.S. 1981a. Sheep and cattle grazing strategies on riparian-stream environments. Pages 251-270 in J.M. Peek and P.D. Dalke, eds. Wildlife - livestock relationships symposium: Proceedings 10. Univ. Idaho, Forest, Wildlife and Range Experiment Station, Moscow. 614 pp. (ADF&G, Habitat Library, #R3906.)

Preliminary results from studies at four locations in Idaho under varying degrees of grazing intensity and strategy are presented in this paper. The effects of both cattle and sheep grazing on stream riparian habitat are discussed as they relate to the herding, holding (continuous), and rest- rotation strategies of grazing.

Initial results indicate that herded sheep grazing may have little effect on streams and riparian environment primarily because the herder can control use in riparian zones (in these studies only 2% of the streamside herbage was utilized by sheep). Under a holding strategy (continuous grazing), with heavy forage utilization (75%), sheep cause much the same impacts as does high (60 to 65% or more) forage utilization by cattle under a rest-rotation system.

Significant differences (95% confidence level) in environmental conditions occurred between the heavily (in excess of range capacity) grazed area and the area that received light (conservative forage removal, which usually improves range vegetation and soil conditions) or no grazing. When sheep were grazed in large numbers on the riparian-stream system of the heavily grazed area, the stream became four times wider and only one fifth as deep. Streambanks were sloped away from the channel, alteration was 15 times greater, undercut banks were almost eliminated, and the quality of riparian habitat decreased. In addition, four times as much stream surface was exposed to solar radiation, and water depth at the streambank interface was only one thirteenth as deep as in the lightly grazed area. Fish density and biomass (average from 1978 through 1980) in the lightly grazed stream reach were 7.6 to 10.9 times greater, respectively, per unit area than in the heavily grazed reach. Trout numbers per 183 m of stream were only about 1.7 times greater in the lightly grazed pastures versus the heavily grazed pasture. Density is so much higher in the lightly grazed pasture because stream width is much narrower.

Cattle grazing studies discussed in this report are from the early stages of a multiyear project that has not been completed. Trends that have developed after two years of the study indicate that cattle grazing under the rest-rotation strategy have not yet caused detectable changes in the fish population, the water column, or the stream channel environment. Changes that did occur were primarily visual observations, including decreased vegetation and streambank alteration. The cattle-grazing project will test the hypothesis that livestock grazing impacts are small annual microchanges that accumulate over the years. Initial results indicate that the effects of cattle grazing first appear on the streambanks and riparian vegetation. Habitat alteration occurs at utilizations rates of 65% or more, and alteration is insignificant when utilization is 25%.

Activity: grazing.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Platts, W.S. 1981b. Effects of livestock grazing. Vol. 7 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. Series: 1979-. USDA: Forest Service. Pacific Northwest Forest and Range Experiment Station, Portland, OR. Gen. Tech. Rept. PNW-124. 25 pp. (ADF&G, Habitat Library, #B2439.)

This review paper documents information on interactions of livestock and fish habitat. Included are discussions of incompatibility and compatibility between livestock grazing and fisheries, present management guidelines, information needed for problem solving, information available for problem solving, and future research needs.

Livestock grazing can affect all components of the aquatic system. Grazing can affect the streamside environment by changing, reducing, or eliminating vegetation bordering the stream. Channel morphology can be changed by accrual of sediment, alteration of channel substrate, disruption of the relation of pools to riffles, and widening of the channel. The water column can be altered by increasing water temperature, nutrients, suspended sediment, bacterial populations, and in the timing and volume of stream flow. Livestock can trample streambanks, causing banks to slough off, creating false setback banks, and exposing banks to accelerated soil erosion.

Activity: grazing.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; physical trampling or crushing; change in levels of nutrients.

Platts, W.S., and W.F. Megahan. 1975. Time trends in riverbed sediment composition in salmon and steelhead spawning areas: South Fork Salmon River, Idaho. Pages 229-239 in Transactions of the fortieth North American wildlife conference, Pittsburgh, PA. 1975. (ADF&G, Habitat Library, #R2956.)

This paper reports the change in substrate composition in a watershed subjected to overlogging and road construction over an 8-yr period. Riverbed surface conditions deleterious to fish spawning were found where disturbances from logging and road construction were allowed to progress without restriction on steep mountain lands. At the outset of study (1966), the percentage of fines in spawning areas studied ranged from 45 to over 80%. In 1975, the size composition of bottom materials was at or near optimum levels, where fines range from 12-26%; these values were expected to decrease further in future years. These results demonstrate the ability of a natural stream to recover if sediment flows into the stream resulting from accelerated erosion are reduced to levels below the capacity of the stream to flush fines from the system.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials.

Platts, W.W., and J.N. Rinne. 1985. Riparian and stream enhancement management and research in the Rocky Mountains. N. Am. J. Fish. Manage. 5:115-125. (ADF&G, Habitat Library, #R5106.)

This report reviews past stream enhancement research in the Rocky Mountains, its adequacy, and research that should be done to improve the effectiveness of future stream enhancement projects. Research is lacking on stream improvement in a watershed context on a long-term basis. Not all streams can be enhanced. Enhancement should be attempted only after techniques described in the literature have been carefully considered and judged appropriate for the selected site. (Authors' abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats); grazing.

Impact: change in water temperature; change in depth or velocity of water; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Ponce, S.L., and G.W. Brown. 1974. Demand for dissolved oxygen exerted by finely divided logging debris in streams. Forest Research Laboratory, Oregon State Univ., Corvallis. Research Paper 19. 10 pp. (ADF&G, Habitat Library, #R2298.)

The purpose of this work was to quantify the impact of Douglas-fir needles and twigs, western hemlock needles, and red alder leaves on dissolved oxygen and toxins, and thus, the quality of mountain stream water for production of fish. The study consisted of three parts. First, the long-term Biological Oxygen Demand (BOD) under conditions of constant temperature was determined for the material to quantify the amount of oxygen required by microorganisms and the rate at which they used it in the oxidation process under standard conditions. Second, a short-term BOD was determined using simulated stream conditions in which the temperature was fluctuated daily to replicate conditions observed immediately after clear-cutting where slash is allowed to accumulate in the headwaters of a coastal stream fully exposed to sunlight. The third test was determination of toxicity of the leachate to fish.

BOD curves were constructed through the composite data using a least-squares fit. Results for BOD at the standard temperature clearly point out that finely divided logging debris has the potential to exert a substantial demand on a stream's oxygen supply. Douglas-fir needles exerted the lowest demand over 90 d (115 mg O_2/g leaves) of the three types of leaf material tested, but at the same time had the highest reaction rate coefficient. In studies such as this, emphasis generally is put on the total quantity of oxygen extracted by a material, but the rate at which oxygen is extracted is often more important. Because of the high reaction rate coefficient, the oxidation process for Douglas-fir needles occurs rapidly; nearly 95% of the BOD at 90 d is reached by day 20. In other words, Douglas-fir needles are most likely to create a substantial reduction in the dissolved oxygen concentration the first 20 d in the stream. After 20 d, the BOD exerted per day is low. Western hemlock needles and red alder leaves both exert a BOD over 90 d much greater (1.8 and 2.5 times, respectively) than the Douglas-fir needles. The reaction rate for both species is slightly less than one-third that of Douglas-fir needles. As a result, the oxygen demand exerted by these materials is initially lower per day than for the Douglas-fir needles, but after 20 d it is greater. This situation results in a relatively constant demand on a stream's oxygen supply.

The toxicity levels found were considered to be extremely low for such a concentrated sample, so low that they probably would pose no threat to fish in a flowing stream. Demand for oxygen by the leachate probably would be responsible for death before the direct effect of the leachate constituents. (Author's discussion: partial and modified)

Activity: clearing and tree harvest.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

Pratt, S.D., S.B. Daila, A.G. Gaines, and J.E. Krout. 1973. Bio-logical effects of ocean disposal of solid waste. Univ. Rhode Island, Mar. Tech. Rept. Ser. No. 9. 53 pp. (ADF&G, Habitat Library, #B6270.)

A laboratory study was conducted to test the effects of dumping shredded and compacted residential solid waste into marine waters. Oxygen was consumed in 6 to 8 d. Hydrogen sulfide was produced after 50 d and continued to increase in concentration. Ammonia reached toxic concentrations in interstitial waters. The effects of toxic metals contained in the solid waste were not studied. The species most sensitive to the waste was a marine fish and shrimp were killed by the hydrogen sulfide.

Activity: solid waste disposal.

Impact: change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - sulfurous compounds.

R and M Consultants, Inc. 1977. Water quality management related to design, construction and maintenance of transportation corridors. Summary report 208 planning study. Prepared for ADEC. 106 pp. (ADF&G, Habitat Library, #B6287.)

This report is specifically concerned with transportation corridors, namely roads, railroads, and pipelines constructed and maintained within the state. The conclusions made from this report are that 1) existing transportation systems have created relatively minor impact upon water quality to date; 2) the technical solutions to adequately prevent or minimize water quality degradation resulting from erosion and sedimentation are readily available but not uniformly practiced; and 3) the principle problem lies in effective and equitable regulation and enforcement of erosion control standards.

A number of types of erosion are defined in the introduction of this report. Of major concern in this report is "accelerated erosion," which is defined as "more rapid than normal, natural, or geological erosion, primarily as a result of the activities of man or, in some cases, of animals." The objectives of this project were to define the extent of this problem by 1) identifying erosion and sedimentation as related to transportation corridors in Alaska; 2) reviewing the existing conditions and practices of transportation systems in the state; 3) describing the technical solutions practiced in Alaska and elsewhere to prevent or control erosion and resultant sedimentation; and 4) reviewing the existing legal and institutional situation, at the state and federal level, responsible for both the regulation and enforcement of water quality legislation as well as the construction of transportation systems.

Activity: clearing and tree harvest; grading/plowing; transport personnel/equipment/material - land.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen.

Rankin, D.P. 1979. The influence of un-ionized ammonia on the long-term survival of sockeye salmon eggs. Fish. Mar. Serv. Tech. Rept. 912. 17 pp. (ADF&G, Habitat Library, #B0934.)

The purpose of this investigation was to estimate threshold levels of un-ionized ammonia causing egg mortality. In addition, the effect of ammonia and pH on daily hatching rates and the size of the surviving alevins were examined and results presented.

Sockeye salmon (Oncorhynchus nerka Walbaum) eggs were exposed, from fertilization to hatching, to constant levels of un-ionized ammonia (NH_3) from 0.099 to 4.05 mg NH_3-/l at 10 degree C and a pH of 8.4. Eggs were also raised in a water-only control (pH = 7.4) and a buffer-only control (ph = 8.4) to determine base mortalities. Total (100%) mortality occurred at concentrations above 0.999 mg NH_3-N/l.

The median tolerance limit for the entire period from fertilization to hatching (62 d) was estimated at 0.11 mg NH_3-N/l. There was a linear increase in the time to 50% mortality from 23 d at 4.05 mg NH_3-N/l.

Un-ionized ammonia and buffer influenced hatching rates; 9.4% of the alevins exposed to 0.099 mg NH_3-N/l hatched before any of those in the water-only control. In addition, ammonia and high pH affected size at hatching: alevins in the treatment and buffer-only control were significantly smaller than those in the water-only control. (Author's abstract)

Activity: log storage/transport.

Impact: change in levels of other toxic compounds - other.

Ray, S., and J. Coffin. 1977. Ecological effects of cadmium pollution in the aquatic environment: a review. Fish. Mar. Serv. Tech. Rept. No. 734: 24 pp. (ADF&G, Habitat Library, #B1609.)

This paper reviews the current literature with reference to the occurrence, uses, properties and effects of cadmium on aquatic biota, with emphasis on fish and shellfish.

Cadmium is known to be an extremely toxic accumulative poison and had been defined as a stock pollutant. Uncontaminated surface waters may contain an average of less than 1.0 ug Cd/kg, while concentrations in contaminated waters may reach a value several magnitudes higher. Many aquatic species, especially fish and shellfish, have the ability to concentrate cadmium in their bodies above ambient levels, with long-term effects that are not yet fully determined.

Cadmium operates slowly and it appears that a 96-h bioassay test may not be of sufficient duration to evaluate its toxicity to fish. Again, tremendous differences have been observed between static and continuous bioassy results. The flow-through bioassay, which better simulates natural conditions, should be adopted as a standard procedure if any ecologically meaningful results are to be achieved. The static test can be used only for preliminary screening. Short-term exposure tests on embryonic or larval stages to estimate chronic toxicity may be advantageous, since these are the most sensitive stages and would be indicative of chronic toxicity.

Activity: processing minerals; sewage disposal.

Impact: change in levels of heavy metals.

Read, P.A., K.J. Anderson, J.E. Matthews, P.G. Watson, M.C. Halliday, and G.M. Shiells. 1983. Effects of pollution on the benthos of the Firth of Forth. Mar. Pollut. Bull. 14(1):12-16. (ADF&G, Habitat Library, #R3905.)

A long-term benthic study has been undertaken to assess the environmental impact of a new sewage treatment scheme for the city of Edinburgh, Scotland. The new scheme reduces the suspended solids and achieves a lowering of the concentration of materials in solution through more efficient dilution and dispersion. Changes in the intertidal benthic flora and fauna have been recorded along the coastal zone since the new treatment was begun. Populations of certain pollution-indicator species have declined and disappeared, and several previously unrecorded species have been established along the more polluted parts of the Edinburgh shoreline. Study of the sublittoral benthos has shown no deleterious effect from the new effluent outfall, and there appears to be some enhancement of the local fauna. This enhancement indicates that the diffuser for the outfall is spreading the effluent over a fairly large area and that increased nutrients have increased faunal populations.

Activity: sewage disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in levels of other toxic compounds - sulfurous compounds; change in levels of nutrients.

Redding, J.M., and C.B. Schreck. 1980. Chronic turbidity and stress in juvenile coho salmon and steelhead trout. Rept. to USFS, PNW-1705-16. 84 pp. (ADF&G, Habitat Library, #R1912.)

The goal of this project was to assess the general physiological responses of stress in coho salmon and steelhead trout to suspended solids in the aquatic environment and to relate these responses to each species' capacity to survive and perform necessary physiological functions.

Juvenile coho salmon and steelhead trout exposed to high (1.7-2.7 g/l) concentrations of suspended (sandy loam) topsoil were found moderately stressed (stress was measured as elevation of plasma cortisol), but these fish acclimated within 7-8 d. Generally, exposure to low levels of suspended topsoil (0.4-0.6 g/l) did not cause significant stress; however, results suggest that some fish can be stressed at even low levels of sediment concentration.

Mortality rates were unaffected by exposure to suspended top soil in all experiments for both juveniles and fry.

Activity: dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments.

Reed, R.D., and S.T. Elliott. 1972. Effects of logging on Dolly Varden. ADF&G Fed. Aid in Fish Rest., Div. Sport Fish. Proj. F-9-4., Job R-IV-B. 62 pp. (ADF&G, Habitat Library, #B1768.)

This report presents the results of the second year of study on the effects of logging on Dolly Varden. Study emphasis included general surveys of logged streams throughout Southeast Alaska; aquatic insect surveys; monitoring prelogging fish populations of eight streams within the Hood Bay watershed; and compiling an annotated bibliography on effects of logging on fish.

Twenty-two logged watersheds located throughout Southeast Alaska were surveyed. Familiarization and photographic documentation of the most common logging damage to streams was obtained.

During surveys, aquatic insect populations were sampled to obtain species composition and distribution of the more common species. Comparisons were made between logged and unlogged areas, which revealed a decrease in species diversity within the altered stream sections.

No significant changes in fish population sizes were noted. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing; stream crossing - fords; stream crossing - structures.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions; introduction or removal of species.

Rees, W.H. 1959. Effects of stream dredging on young silver salmon (Oncorhynchus kisutch) and bottom fauna. Washington Department of Fisheries, Fish. Res. Pap. 2(2):53-65. (ADF&G, Habitat Library, #R2951.)

A program was conducted in 1952 and 1953 to measure the effects of dredging and stream channeling on juvenile salmonids and bottom organisms in Little Bear Creek, a small stream 15 mi northeast of Seattle that is populated by silver salmon.

Dredging in September 1952 eliminated 97% of the bottom organisms in the test area. The dredged area showed a reduced fauna population for 5 m and then began to recover in February 1953. By July 1953, the creek had recovered completely.

Population estimates of age 0 silver salmon and trout fingerlings showed a decrease of 69 and 81%, respectively, immediately after dredging in September 1952. Fish were killed by the drag line or by being trapped in various isolated sections of the old channel. Physical alteration of the stream bed also caused indirect effects such as destruction of the juvenile salmonid and macroinvertebrate food supply and elimination of suitable living area. Population estimates made 1 yr after dredging (August 1953) demonstrated complete recovery. (Author's summary: modified)

Activity: channelizing waterways; dredging.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Reger, S.J., and W.T. Helm. 1982. Effects of stream channel alterations on aquatic insect communities in Cache Valley, Utah. Pages 466-475 in Proceedings 62nd annual conference of the Western Association of Fish and Wildlife Agencies. Las Vegas, Nevada July 19-22, 1982. (ADF&G, Habitat Library, #R3565.)

The Logan River system study evaluated effects of channel alterations on floodplain areas where the situation was complicated by agricultural usage. Four sites were compared: 1) a control, 2) an area bulldozed in 1971 that had remained relatively constant, 3) an area dredged twice by backhoe in 1975, and 4) an area bulldozed in 1971 and again in 1975.

Community composition changed for a relatively short period following alterations--diversity decreased belatedly (a function of faster recolonization by baetids, chironomids, and simuliids). Alterations greatly reduced macroinvertebrate density and standing crop for a short time. There was some evidence that dredging produced slightly longer-lasting effects--due to greater substrate instability. The duration of the impact on the benthic community was largely dependent on the time required for the return of substrate stability. Other factors controlling the recovery of macroinvertebrates were time of year of the alteration and the rate of return of the food base.

Mean standing crop and production were highest at the site bulldozed in 1971, but diversity was lowest because of the uniformity of substrate. The control site had the second highest mean standing crop and production and the highest diversity. The areas bulldozed and dredged in 1975 were third and fourth, respectively, in mean standing crop and production and mean annual standing crop estimate proved to be as useful as production for comparison. Differences in standing crop and production were correlated to substrate stability, in contrast to fish production which was correlated to other habitat changes, particularly the removal of pools.

Similar seasonal patterns were found in all sites, although recent alterations overrode "normal" seasonal differences. A low-water year in 1976, introduction of a toxicant, possibly from irrigation runoff, in 1975, and differences in flow patterns were confounding variables.

Activity: channelizing waterways.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Reiser, D.W. 1981. Effects of streamflow reduction, flow fluctuation, and flow cessation on salmonid egg incubation, and fry quality. Ph.D. Thesis, Univ. Idaho. 236 pp. (ADF&G, Habitat Library, #B1826.)

Laboratory and field tests were conducted from 1977 to 1980 to evaluate the effects of reduced streamflow, streamflow fluctuation, and flow cessation (dewatering) on salmonid embryo incubation and fry length and weight. Reductions in streamflow over redds containing from 3 to 13% sediment resulted in increased embryo mortality. The greatest increase in mortality occurred with flow reductions addociated with sediment levels of 7% sediment less than 0.84 mm. Flow reductions may retard development of embryos and may result in higher mortalities if the flow reduction is made after the circulatory system is functional. Water depths and velocities over redds are poor indicators of intragravel velocities and therefore not useful in predicting embryo survival. Chinook and steelhead embryo survival was positively correlated with intragravel flow velocity. Chinook fry length was positively correlated with intragravel velocity during sediment-free flow-reduction tests. Sediment of less than 0.84 mm was the most deleterious to embryo survival and should be limited to levels of less than 10%. In laboratory flow-reduction tests, no significant differences in survival were found between embryos periodically dewatered (11-12 h/d) and those continuously watered. The rate of dewatering may influence embryo survival. It may be less harmful if embryos are dewatered quickly, avoiding long periods within nonmoving water. Embryo development may be delayed in redds periodically exposed if intragravel temperatures are colder than water temperatures. Thermal shock, air entrapment, and gravel settling may occur as a result of flow fluctuations and could adversely affect embryo survival. Steelhead and chinook embryos were tolerant to long periods of dewatering (1 to 5 wk), with no significant effects on survival, hatching, growth rates, or fry quality. Alevin dewatering tolerance limits are estimated to be less than 10 h. Gravel moisture levels of 4% or more were sufficient to maintain healthy salmonid embryos and allow normal embryogenesis. Spawning criteria for chinook and steelhead were developed.

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Reiser, D.W. and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in the western United States and Canada. 1. Habitat requirements of anadromous salmonids. W.R. Meehan (ed.). USDA For. Serv., Gen. Tech. Rept. PNW-96. 54 pp. (ADF&G, Habitat Library, #B2439.)

Habitat requirements of anadromous and some resident salmonid fishes have been described for various life stages, including upstream migration of adults, spawning, incubation, and juvenile rearing. Factors important in the migration of adults are water temperature, minimum water depth, maximum water velocity, turbidity, dissolved oxygen, and barriers. Habitat requirements for successful spawning are suitable water temperature, water depth, water velocity, and substrate composition. Cover -- riparian vegetation, undercut banks, and so on -- is needed to protect salmonids waiting to spawn and may influence the selection of spawning locations.

Incubation requirements incorporate both extra- and intragravel factors. Extragravel factors are: dissolved oxygen, temperature, velocity, discharge, and biochemical oxygen demand of the stream. Intragravel factors are dissolved oxygen, temperature, permeability, apparent velocity, and sediment composition. Important habitat components for juvenile rearing are fish food production areas, water quality, cover, and space. Good fish food production areas are mostly riffles with water depths of 0.15 - 0.91 m, water velocities of 0.30 - 0.46 m/s, and substrates of coarse gravel and rubble (3.2 - 30.4 cm). Good water quality for rearing salmonids includes mean summer water temperatures of 10.0 - 14.0°C, dissolved oxygen at more than 80% saturation, suspended sediment less than 25 mg/l, and fine sediment content of riffles less than 20%. Adequate cover -- in the form of riparian vegetation, undercut banks, aquatic vegetation, and rubble-boulder areas -- is needed to protect juvenile fish from predation and adverse physical factors. (Authors Abstract).

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline; change in level of dissolved oxygen, nitrogen.

Reiser, D.W., and M.P. Ramey. 1985. Review of flushing flow requirements in regulated streams. Pac. Gas and Electric Co., Dept. of Eng. Res. Contract No. Z19-5-120-84 San Ramon, CA. 97 pp. + appendices. (ADF&G, Habitat Library, #B6204.)

This report presents a technical review of many of the biological and engineering considerations needed for assessing flushing flow requirements in regulated streams. The regulation of streamflows can alter the natural regime of a system by removing peak flows and reducing the stream sediment transport competency. The net effect can be that sediment inputted to the system tends to accumulate rather than being periodically removed (flushed) as during spring runoff. The deposition and aggradation of sediments ultimately becomes a problem when it affects the biotic community. In this case, a release flow (flushing flow) simulates high runoff events may be periodically needed to remove fine sediments from the stream. Emphasis is placed on defining a set of guidelines and presenting specific considerations and techniques for assessing the need for and magnitude, timing, and effect- iveness of flushing flows. The report further describes 15 methods and approaches currently being used for estimating flushing flows. (Author's summary: partial)

Activity: water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; change in level of dissolved oxygen, nitrogen.

Reiser, D.W., and R.G. White. 1983. Effects of complete redd dewatering on salmonid egg-hatching success and development of juveniles. Trans. Am. Fish. Soc. 112(4):532-540. (ADF&G, Habitat Library, #R3617.)

The effects of prolonged stream dessication on development of salmonid eggs were simulated for steelhead (Salmo gairdneri) and spring chinook salmon (Oncorhyncus tshawytscha). The experiments took place at the Idaho Department of Fish and Game's Hayden Creek Research Station near Lemhi, Idaho. Tests began on May 22, 1979, for steelhead and on September 6, 1979, for chinook salmon. Recently fertilized eggs were placed in artificial redds and subjected to controlled water flows in outdoor laboratory channels. Control redds were continuously submerged. "Dewatered" redds were exposed to air; water flowed through the substrate 10 cm below the eggs. Eggs were dewatered 1-4 wk (steelhead) or 1-5 wk (chinook salmon) before they were returned to water in hatchery incubators, where hatching success and subsequent fry development were monitored. Several combinations of cobble, coarse sediment, and fine sediment used to cover eggs did not influence egg development, provided the mixtures retained at least 4% moisture by weight and provided the sediments neither froze nor reached temperatures that exceeded incubation tolerances.

Oxygen transport to embryos in dewatered redds probably occurs via the influx of air into gravel interstitial spaces, the dissolving of oxygen into the thin layer of water surrounding the egg, and the subsequent diffusion of oxygen through the egg capsule. If precipitation is discounted as a source of moisture replacement, two mechanisms acting with the gravel may help sustain "high" moisture levels. The first, capillary action, entails the upward movement of water from the water table through the sediment (gravel) interstices. This process is impeded by trapped air and large soil pores and, for this reason, probably only operates in substrate mixtures containing abundant fine sediments or at locations where the water table is close to the eggs. The second mechanism, water-vapor transfer, results from a vapor-pressure gradient between two adjoining areas; the mechanism is likely responsible for moisture replenishment in the coarse textured gravels characteristic of salmonid redds. Thus, if ground water levels remain close to dewatered eggs, the eggs should remain moist. However, the specific distances from eggs to groundwater within which these moisture-replenishing mechanisms operate are unknown. Dewatered eggs hatched sooner than control eggs; faster hatch was associated with higher substrate temperature in exposed redds. Hatching success of dewatered eggs averaged 94% for steelhead (control: 88%) and 76% for chinook salmon (control: 56%) and was not affected by the time eggs had been dewatered. After 8 (chinook salmon) and 8.5 (steelhead) wk of rearing, juveniles from dewatered and control eggs had grown equally well.

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments.

Rice, S.D. 1981. Review: effects of oil on fish. National Academy of Sciences Workshop on Petroleum in the Environment, Nov. 1981. NMFS, Auke Bay Laboratory, Alaska. 34 pp. (ADF&G, Habitat Library, #R3904.)

In Rice's review of oil impacts on fish he notes several areas that have not been studied; one is that field studies after an oil spill have not looked for changes in fish populations. Studies suggest that fish might avoid contaminated areas, but fish have complex behavior and physiology that make it difficult to predict the effects of oil on fish populations. Rice also advises careful evaluation of studies on oil effects of eggs and larvae. Often the seriousness of the damage to an embryo is not apparent until the eggs hatch, even though eggs may survive exposure to oil. The earlier an embryo is exposed to oil, the more severely it is damaged. After the larva hatches, its sensitivity increases again until the yolk is absorbed.

Rice notes that interference with reproduction as a result of oil exposure is another area that has received little attention. The lowest levels of oil contamination that could damage fish populations are those that affect the ability of individuals to reproduce, either by causing malformation of gonads or gametes or by decreasing the energy the fish can invest in growth and reproduction. Although fish may avoid an oil spill, a change in the behavior of prey species may attract fish to an area. Rice cites a study showing that when plaice are given a choice between oiled and unoiled shrimp, they preferentially eat the oiled ones, probably because the oiled shrimp are easier to catch.

General conclusions drawn by the author include the following: 1) Petroleum pollution can harm fish harvest through direct destruction of fish, tainting of the catch, or loss of fishing time or gear. 2) Destruction of a fishery from oil pollution may be caused in several ways, such as fish kills, failure of successful spawning and recruitment, or changes in habitat, behavior, or migration patterns. 3) Refined oils are composed of higher concentrations of aromatic hydrocarbons and are generally more toxic than crude oils. 4) Toxicity of aromatic oil components of fish and invertebrates increases as the molecular size increases. 5) Pelagic fish species tend to be more tolerant to water-soluble fractions of oil than are benthic fish species. 6) In general, fish are more sensitive to short-term oil toxicity than are most invertebrates. 7) Stress factors, such as fluctuations in salinity, temperature, and food abundance, reduce the ability of fish to cope with petroleum hydrocarbon pollution. 8) The early life stages of fish are more sensitive to oil contaminants than are later stages. Note that his conclusion differs from that of Moles et al. 1979, where embryos were found to be more tolerant of benzene than were alevins. This discrepancy is likely due to the method used by Moles et al. to evaluate "tolerance." They used survival as a measure of tolerance; (see above annotation), which has been reported to be an insensitive method. Particularly sensitive periods are the development of parental gonads, the early development of fertilized eggs, and the transition of larvae from dependence on yolk to feeding. 9) The rate and quantity of uptake of hydrocarbons will depend to some extent on exposure concentration and size of the molecules of compounds. 10) As petroleum hydrocarbons are accumulated in fish, many compounds will be metabolized and/or excreted. 11) Presumably, secretion of aromatic hydrocarbons and their metabolites from the liver into the bile is the major pathway of excretion. 12) Although an exposure to oil may be sublethal, it may be stressful enough to change the delicate balance between organisms, their environment, and disease. Sublethal effects include fin erosion, reduction in rate of tissue regeneration, and decreased growth. 13) Exposure to hydrocarbons has caused delayed hatching in several fish species, as well as stimulation of hatching in others. 14) In laboratory studies, several species of fish detect and avoid low concentrations of hydrocarbons in water.

Activity: drilling; transport of oil/gas/water - water; transport personnel/equipment/material - land.

Impact: change in levels of hydrocarbons.

Rice, S.D., and J.E. Bailey. 1980. Survival, size, and emergence of pink salmon, _Oncorhynchus gorbuscha_, alevins after short- and long-term exposures to ammonia. Fish. Bull. 78:641-648. (ADF&G, Habitat Library, #R3702.)

Eggs and alevins of pink salmon, _Oncorhynchus gorbuscha_, were exposed to ammonia in a series of static and flow-through experiments to determine what levels of ammonia would decrease survival. Short-term acute toxicity tests (96 h) were conducted at several stages in development to determine which of the early life stages were most sensitive to ammonia. Long-term tests (up to 61 d) with lower ammonia concentrations were conducted to determine effects on survival and size of fry at emergence. The possibility of ammonia stimulating emergence of immature fry was tested at various stages of development.

Pink salmon alevins were most sensitive at the completion of yolk absorption, when the 96-h median tolerance limit was 83 ppb of un-ionized ammonia. Concentrations as low as 1.2 ppb reduced dry length in the 61-d exposures. Only levels above 10 ppb of ammonia stimulated early emergence of immature fry.

The concentrations of ammonia causing any of the deleterious effects observed are greater than concentrations observed in the hatchery or the natural environment. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in levels of other toxic compounds - other.

Rice, R.M., J.S. Rothacher, and W.F. Megahan. 1972. Erosional consequences of timber harvesting: an appraisal. Pages 321-329 in Proceedings, American Water Resources Association, national symposium on watersheds in transition, 1972. Pacific Southwest Forest and Range Experiment Station, Glendora, CA. (ADF&G, Habitat Library, #R3923.)

This paper summarizes the effects of timber harvesting on erosion. Rates of erosion on mountain watersheds vary widely, but the relative importance of different types of erosion and the consequences of disturbances remain fairly consistent. Therefore these conclusions seem to be valid for most circumstances:

1. Most of man's activities will increase erosion to some extent in forested watersheds.

2. Erosion rarely occurs uniformly.

3. Sediment production declines rapidly following disturbance.

4. Landslides and creep are the chief forms of natural erosion in mountainous regions.

5. Cutting of trees does not significantly increase erosion, but clear-cutting on steep unstable slopes may lead to increased mass erosion.

6. Accelerated erosion is a possible undesirable side effect of use of fire in conjunction with logging.

7. The road system built for timber harvesting far overshadows logging or fire as a cause of increased erosion.

8. Potentially hazardous areas can be identified in advance of the timber harvest.

(Author's conclusions: modified)

Activity: burning; clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Rice, S.D., D.A. Moles, and J.W. Short. 1975. The effect of Prudhoe Bay crude oil on survival and growth of eggs, alevins, and fry of pink salmon, *Oncorhynchus gorbushcha*. Pages 503-507 *in* 1975 Conference on prevention and control of oil pollution, proceedings, American Petroleum Institute, Washington, D.C. (ADF&G, Habitat Library, #R3695.)

Standard 96-h tests with "total" oil solutions in fresh water and sea water determined differences in sensitivity of the developing life stages of pink salmon (*Oncorpynchus gorbuscha*). Eggs were the most resistant and emergent fry (yolk sac absorbed) the most sensitive to acute 4-d exposures. In fresh water, the 96-h median tolerance limit (TLm) of fry was 0.4 ml oil/l mixed mechanically (12 ppm as measured in subsurface water by infrared spectrophotometry). In sea water, it was 0.04 ml oil/l mixed mechanically (6 ppm as measured in subsurface water by infrared spectrophotometry).

Three life stages of alevins were exposed to 10-d sublethal exposures of the water-soluble fraction to determine what does might affect growth. Growth was affected most severely in alevins exposed during later developmental stages. Decreased growth was observed in fry after 10-d exposures at the lowest does tests--0.075 ml oil/l mixed by water agitation (0.73 ppm in subsurface water by infrared spectrophotometry--less than 10% of the 96-h TLm limit for that life stage).

In fresh water, susceptibility of early life history stages of pink salmon to oil pollution is great at the time of emergence (completion of yolk absorption). Susceptibility is even greater in sea water after fry migration. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Rice, S.D., J.W. Short, and J.F. Karinen. 1976a. Toxicity of Cook Inlet crude oil and No. 2 fuel oil to several Alaskan marine fishes and invertebrates. Pages 395-406 in Sources, effects and sinks of hydrocarbons in the aquatic environment, Proceedings of the symposium, American Univ. Wash., D.C., 9-11 Aug. 1976. American Institute of Biological Sciences, Washington, D.C. (ADF&G, Habitat Library, #R3647.)

A 96-h static-test method was used to determine the median tolerance levels (TLms) of 27 different invertebrate and vertebrate Alaskan marine species exposed to water-soluble fractions (WSFs) of Cook Inlet crude oil and No. 2 fuel oil. Concentrations of oil in the exposure doses of the WSFs were determined by infrared spectrophotometry.

The two different oils were about equally toxic. No. 2 fuel oil was somewhat more toxic than the Cook Inlet crude oil to some of the species. Fish were consistently among the more sensitive species with 96-h TLms from 0.81 to 2.94 ppm. Some invertebrates were as sensitive as fish, whereas others were quite resistant. Intertidal invertebrates were consistently among the most resistant species.

It appears that Alaskan marine species may be slightly more sensitive than similar species residing in more temperate regions. However, the differences in observed sensitivity may be due to the greater toxicity of oil at lower temperatures (because of greater persistence of hydrocarbons) rather than to actual increases in the sensitivity of the animals. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Rice, S.D., J.W. Short, C.C. Brodersen, T.A. Mecklenburg, D.A. Moles, C.J. Misch, D.L. Cheatham, and J.F. Karinen. 1976b. Acute toxicity and uptake-depuration studies with Cook Inlet crude oil, Prudhoe Bay crude oil, No. 2 fuel oil, and several subarctic marine organisms. NWFC processed rept. 90 pp. Auke Bay Laboratory, NWAFC, NMFS, NOAA, P.O. Box 210155, Auke Bay, AK 99821. (ADF&G, Habitat Library, #B6471.)

The results of this study do not suggest that major differences exist between the responses of the Alaskan marine animals tested and the responses of marine animals from other areas as reported in the literature.
The concentration of oil-in-water dispersions and water-soluble fractions of oil in solutions is dependent on a number of factors including oil volume, confinement of the oil, mixing duration, and mixing energy. As a result, the authors do not attempt to transfer the results of this study to a field situation (including Kachemak Bay) or establish the potential effects of oil contamination on the environment. If oil pollution did occur, the oil concentrations that would occur in the water column are difficult to predict since the oil volume, mixing duration, mixing intensity, and confinement of the spill are all important but unknown variables that would depend on the specific conditions prevailing at the time of the spill. Further, there are too few quantitative studies on the effects of an oil spill in arctic and subarctic waters that include measurements of oil in the water column for us to state that our laboratory exposure concentrations might be encountered under a field spill situation. (Author's conclusions)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Rice, S.D., J.W. Short, and J.F. Karinen. 1977a. Comparative oil toxicity and comparative animal sensitivity. Pages 78-94 in D.A. Wolfe, ed. Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems, Proceedings of a symposium, 10-12 Nov. 1976, Seattle, Wash. New York: Pergamon Press. (ADF&G, Habitat Library, #R3704.)

The scope of this review is limited to studies dealing with the ability of crude and refined oils to kill marine animals. Emphasis is given to the more recent quantitative studies that were not available to earlier reviewers: 1) the behavior of oil in water; 2) the methodology problems associated with tests; 3) the comparative toxicity of oil-water mixtures, oils, and components of oils; and 4) the comparative sensitivity of different life stages and species. (From Rice et al. 1984).

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Rice, S.D., R.E. Thomas, and J.W. Short. 1977b. Effect of petroleum hydrocarbons on breathing and coughing rates and hydrocarbon uptake-depuration in pink salmon fry. Pages 259-277 in F.J. Vernberg, A. Calabrese, F.P. Thurberg, and W.B. Vernberg, eds. Physiological responses of marine biota to pollutants, proceedings. New York: Academic Press. (ADF&G, Habitat Library, #R3703.)

1. The water-soluble fraction (WSF) from Cook Inlet and Prudhoe Bay crude oils and No. 2 fuel oil causes similar increases in breathing and coughing rates in pink salmon fry.

2. Breathing and coughing rates increase in proportion to oil concentrations, as measured by ultraviolet but not by infrared spectrophotometry. This suggests that naphthalenes rather than paraffins are responsible for this effect. Significant responses were detected at about 30% of the 96-h TLm.

3. Breathing and coughing rates of pink salmon fry remained above normal during exposure to a constant dose of oil for 72 h.

4. Paraffinic, monoaromatic, and diaromatic hydrocarbons were found in tissues of fish exposed to the WSF of Cook Inlet crude oil. The fish started apparent depuration of the aromatic hydrocarbons during the first 24 h of exposure; this indicates that they can cope with the stress physiologically. Our data support the concept of excretion through the liver-gall bladder-gut.

5. High breathing rates during the first 14 h of exposure, elimination of most aromatic hydrocarbons by 20 h, and the continued high breathing rates during the constant-dose exposure for 72 h indicate that salmon fry can cope with a sublethal exposure to hydrocarbons, but at the cost of an increased metabolic rate. Increased metabolic rates may be detrimental to survival if the stress persists for long periods of time. (From Rice et al. 1984.)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Rice, S.D., A. Moles, T.L. Taylor, and J.F. Karinen. 1979. Sensitivity of 39 Alaskan marine species to Cook Inlet crude oil and No. 2 fuel oil. Pages 549-554 in Proceedings 1979 oil spill conference (prevention, behavior, control, cleanup). American Petroleum Institute, Washington, D.C. (ADF&G, Habitat Library, #R3696.)

The sensitivities of 39 subarctic Alaskan species of marine fish and invertebrates to water-soluble fractions of Cook Inlet crude oil and No. 2 fuel oil were determined. This is the largest group of animals ever tested under similar test conditions with the same petroleum oils and analytical methods. Organisms tested represent several habitats, six phyla, and 39 species, including fish (9), arthropods (9), mollusks (13), echinoderms (4), annelids (2), and nemerteans (2). Sensitivities were determined by 96-h static tests. Concentrations of selected aromatic hydrocarbons were determined by gas chromatography; concentrations of paraffins were determined by infrared spectrophotometry.

Although sensitivity generally increased from lower invertebrates to higher invertebrates, and from higher invertebrates to fish, sensitivity was better correlated to habitat. Pelagic fish and shrimp were the most sensitive animals to Cook Inlet crude oil with 96-h median tolerance limits (TLms) of 1-3 mg/l total aromatic hydrocarbons. Benthic animals, including fish, crabs, and scallops were moderately tolerant (TLms to Cook Inlet crude oil of 3-8 mg/l total aromatic hydrocarbons). Intertidal animals, including fish, crabs, starfish, and many molluscs, were the most tolerant forms to water-soluble fraction of petroleum (TLms greater than 8-12 mg/l of total aromatic hydrocarbons). Most of the intertidal animals were not killed by static oil exposures. Number 2 fuel oil was more toxic to most species than Cook Inlet crude oil.

Sensitive pelagic animals are not necessarily more vulnerable to oil spills than tolerant forms. Oil may damage intertidal environments more easily, and adverse effects may damage intertidal environments more easily, and adverse effects may persist longer than in damaged pelagic environments. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Rice, S.D., S. Korn, and J.F. Karinen. 1981. Lethal and sublethal effects on selected Alaskan marine species after acute and long-term exposure to oil and oil components. Pages 61-78 in Environmental assessment of the Alaskan continental shelf. Ann. rept. 1981. Vol. 4: Effects of contaminants. 677 pp. (ADF&G, Habitat Library, #R3918.)

The main objective in this report was to determine the vulnerability of pink salmons alevins exposed to four different exposure schedules of the water soluable fraction of Cook Inlet oil in a simulated intertidal spawning environment.

Fish continuously exposed to the top dose (2.4 ppm total aromatic hydrocarbons) died in 7-16 d; the late alevins died sooner than the early alevins, and the alevins in the intermittent sea water exposures usually died before their freshwater counterparts. The late alevins receiving the highest concentration of 2.4 ppm in the intermittent oil exposure died in the exposures with intermittent sea water but not in 100% freshwater exposures. No other groups experienced greater than 5% mortability--the same as in the controls. Seawater-oil exposure was apparently more stressful, because the first deaths occured in the intertidal high doses. The early alevins continuously exposed took longer to die than the late alevins, probably because of larger quantities of yolk that absorbed and retained the hydrocarbons in semi-isolation from the developing tissues.

The size of fry was affected by both salinity and oil exposures. However, early alevins were affected less than late alevins, probably because the developmental rate is a little slower at that stage, and effects take longer to become evident.

In all cases, alevins exposed to oil were smaller than the controls, and alevins exposed to sea water were smaller than the freshwater counterparts. Both treatments appear stressful enough to cause increased energy consumption, and, consequently, the fry were smaller. In general, there was little difference between continuous and intermittent oil exposures. The smallest fry were those exposed continuously to the highest oil dose with an intermittent salinity exposure.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Rice, S.D., D.A. Moles, J.F. Karinen, S. Korn, M.G. Carls, C.C. Brodersen, J.A. Gharrett, and M.M. Babcock. 1984. Effects of petroleum hydrocarbons on Alaskan aquatic organisms: a comprehensive review of all oil-effects research on Alaskan fish and invertebrates conducted by the Auke Bay Laboratory, 1970-81. USDC; NOAA, Tech. Memo. NMGS, F/NWC-67. 128 pp. (ADF&G, Habitat Library, #B6247.)

This report reviews and summarizes all oil-effects research by the Auke Bay Laboratory from the beginning of these studies in 1970 through 1981. Both published and unpublished results from 62 studies are included, regardless of funding source. Research is reviewed according to subject (e.g., studies with oil, components, studies at Port Valdez and studies with drilling mud). A bibliography and abstracts are also included.

Studies with crude oil, No. 2 fuel oil, and their components. Results from different studies should be compared with caution because the comparisons can be misleading if exposure methods, chemical analyses, test animals, or life stages are different. Temperature also influences results of studies by affecting evaporation and biodegradation of petroleum hydrocarbons. Some generalizations, however, can be made from the results of our studies. The water-soluble fraction (WSF) of No. 2 fuel oil is consistently more toxic than the WSF of crude oil even though the WSFs of fuel oil contain low concentrations of monoaromatic hydrocarbons. The total toxicity of individual aromatic hydrocarbons in the WSFs did not, however, account for all of the toxicity of the oils; thus, the aromatic hydrocarbons could be, in some cases, interacting synergistically.

Many biological and environmental variables affect sensitivity of Alaskan species to the WSFs of oils. For example, pelagic fish and invertebrates are more sensitive than intertidal species. There can be extreme differences in sensitivity between the life stages of one species. For example, eggs often seem as tolerant as adults to short-term exposures, but abnormalities can appear after the eggs hatch. Salmon (Oncorhynchus spp.) alevins become much more sensitive to oil as they develop and lose their yolk. Crustacean larvae are usually sensitive to WSFs and are affected within minutes of exposure. In fact, the lowest LC_{50} (concentration that killed 50% of the test animals) we have measured was 0.2 ppm aromatic hydrocarbons for Stage VI coonstripe shrimp (Pandalus hypsinotus) larvae exposed to Cook Inlet WSF. The effect of temperature on toxicity of hydrocarbons varies for each species and for the hydrocarbons tested. Low temperatures, however, increase the persistence of hydrocarbons in water. Salinity consistently increases the toxicity of hydrocarbons to salmonids, and juvenile salmonids are about twice as sensitive in seawater as in freshwater.

The rate and quantities of hydrocarbons found in test organisms vary considerably and depend on the compounds tested, the life stages and species of animal tested, and the tissues analyzed.

Naphthalene and methylated naphthalene, for example, reach higher concentrations in the test animals than other aromatic hydrocarbons. Concentrations of aromatic hydrocarbons in crustacean larvae usually equilibrate within minutes to concentrations of aromatic hydrocarbons in the test water, whereas salmon eggs required several days. Fish accumulate aromatic hydrocarbons rapidly, whereas blue mussels (Mytilus edulis) accumulate them more slowly.

Metabolism can be an important mechanism for ridding tissues of hydrocarbons. Of the animals tested, fish had the greatest ability to metabolize hydrocarbons. For invertebrates, however, metabolism does not appear to be important. Fish and invertebrates usually eliminate low molecular weight aromatic hydrocarbons and their metabolities via the gills.

Oil and its components have a variety of sublethal effects that can affect population size. Feeding rates of fish and invertebrates are frequently reduced during long-term exposures to crude oil at concentrations that are 15-30% of the short-term LC_{50}; this, growth and energy available for growth (scope-for-growth or energy budget) are decreased.

Sensitivity of an organism in a laboratory study is different from vulnerability after an oil spill. Laboratory tests isolate one variable at a time, whereas oil spills have many variables operating at the same time, and each spill is unique. Planktonic larvae are among the most vulnerable organisms after an oil spill because they are sensitive to oil, are affected after only minutes of exposure, and cannot avoid spilled oil. In fact, some larvae are killed within minutes by concentrations of crude oil that are < 1 ppm. Other animals, like fish, may be nearly as sensitive as planktonic larvae but can probably avoid an oil-contaminated area. Although intertidal animals are not sensitive to oil spills and may require long-term exposures to about 20-25% of their LC_{50} before growth is affected, many are sessile and must rely solely on physiological tolerance to endure exposure to oil.

Studies at Port Valdez

Effluent from the ballast-water treatment plant at Port Valdez is rapidly diluted, and in the short term, is apparently not toxic. However, concentrations of aromatic hydrocarbons in the effluent were as high as 15 ppm, and dilutions of the effluent as low as 2% (vol/vol) were toxic to some crustacean larvae. Shrimp and fish were less sensitive to the effluent (LC_{50} of 19-43% dilutions) than larvae. Repeated tests with shrimp and fish suggest that the toxicity of the effluent may be caused by contaminants other than aromatic hydrocarbons.

A decrease in the population of Baltic clams (_Macoma balthica_) and the presence of hydrocarbons in sediments near the effluent-treatment facility suggest that a continuous discharge of effluent could cause long-term damage.

Drilling Muds

Because drilling muds are rapidly diluted and have low toxicity, they are probably not toxic to planktonic larvae. Unlike the WSFs of oil, crustacean larvae exposed to drilling muds do not immediately cease swimming or die, and most of the toxicity is apparently caused by physical stress of the particulates in suspension rather than chemical stress. The alkalinity of one mud was quite high, however, and its alkalinity was the primary cause of toxicity. (Author's summary)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Ringler, N.H., and J.D. Hall. 1975. Effects of logging on water temperature and dissolved oxygen in spawning beds. Trans. Am. Fish. Soc. 104(1): 111-121. (ADF&G, Habitat Library, #R2735.)

Temperature and dissolved oxygen content of intragravel water were measured in three Oregon coastal streams between June 1968 and June 1969. In 1966, the watershed of one stream had been completely clear-cut and that of a second stream partially clear-cut in staggered settings. A third watershed was left unlogged.

Clear-cut logging resulted in increased temperature of intragravel water in salmon and trout spawning beds and decreased concentrations of dissolved oxygen. The changes were related largely to reduced forest cover over the stream surface and to deposition of fine sediment in the gravel.

No serious reduction in survival to emergence of coho salmon occurred along with the observed changes in temperature or dissolved oxygen. A decrease in the resident population of cutthroat trout after logging may have been related to these changes. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; addition of substrate materials; alteration of natural cover - riparian vegetation; change in level of dissolved oxygen, nitrogen.

Rishel, G.B., J.A. Lynch, and E.S. Corbett. 1982. Seasonal stream temperature changes following forest harvesting. J. Environ. Qual. 11:112-116. (ADF&G, Habitat Library, #R3840.)

Exposing headwater streams to direct solar radiation by removing forest cover has the potential to cause drastic changes in streamwater temperature regimes. A study was conducted to evaluate the maximum potential impacts and to evaluate the effectiveness of management practices used to control these detrimental effects. The control watershed approach was used.

A clear-cut herbicide experiment on a small, headwater stream increased maximum stream temperatures as early as February and as late as November. The average monthly maximum stream temperature increase was 4.4°C. Stream temperatures above 21°C occurred nearly every day during the summer. Stream temperatures above 25°C were recorded as early as May. The highest stream temperature recorded was 32°C. On an adjacent forested watershed, stream temperatures rarely exceeded 20°C; the highest recorded temperature was 22°C. Minimum stream temperatures on the clear-cut herbicided watershed increased an average of 2°C during the summer months but were as much as 3.9°C lower during the fall and winter months. Diurnal fluctuations as high as 17°C occurred on the clear-cut herbicided watershed compared with only 4°C on the forested watershed. On an adjacent commercially clear-cut watershed, where a buffer zone was left along the perennial stream channels, only slight changes in stream temperature were observed. The average monthly maximum stream temperature increase was less than 1°C; the highest temperature recorded was 23°C. Minimum temperatures remained generally unchanged. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in water temperature; alteration of natural cover - riparian vegetation; change in levels of biocides.

Ritter, D.F. 1979. The effects of channelization on a high-energy river. Envir. Geol. 29-38. (ADF&G, Habitat Library, #R5145.)

Extensive channelization of a high-energy river in southern Montana was accomplished during 1957-1958. The channelization technique applied was the same throughout, even though the fluvial characteristics are considerably different in the upstream and downstream segments of the river. In the braided upstream reach, rubble dikes composed of river bedload that was bulldozed against the channel banks prevent the river from occupying high-stage channels, which traverse the lowest surface in the valley. The river has responded by altering its hydrologic characteristics at any given discharge and by accelerating the lateral erosion where banks have been left unprotected. Downstream where the river is in a single-channel pattern, the dikes have been destroyed because the meandering thalweg, repeatedly shifting its postion and impinging against the base of the dikes, provides the force needed to erode the boulders comprising the dikes. Some bank protection is provided by riprap composed of large sandstone blocks. This method works, however, only if long segments of the channel are riprapped. The various responses of the river in reaches having different channel patterns indicate that some knowledge of local fluvial methanics must be obtained prior to the channeliztion. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials.

Rosenberg, R. 1977. Effects of dredging operations on estuarine benthic macrofauna. Mar. Pollut. Bull. 8(5):102-104. (ADF&G, Habitat Library, #R3605.)

The Byfjord is a 4-km-long fjordlike estuary in Sweden. The fjord entrance has a sill at 11 m and a maximum depth in the center of 50 m. The sill normally prevents water exchange below the halocline (12-15 m), and the water is usually anoxic below about 16 m. The salinity above the halocline is 23 to 27 ppt. The Byfjord receives wastewater from a town of 45,000 and a shipyard. In order to expand the shipyard, about 2 million m^3 of sediments were dredged by one pipeline dredge and two ladder dredges with bottom-dump barges. These operations were carried out during the period January to early June. The spoil was dumped in the center of the fjord. The top sediments to be dredged were heavily polluted with mercury (1-6 ppm dry wt) and PCB (0.7-7 ppm), whereas the layers below 0.5 m were nonpolluted clay.

The primary effects of dredging operations were due to the increased amount of suspended particles. The spoil was disposed in the anoxic part of the fjord and had no direct effects on the benthic fauna. The increased turbidity was most probably the reason for the heavily reduced recruitment of benthic species in the vicinity of the dredged area. High concentrations of trace elements were found in deposit feeders (crabs) when compared to filter feeders (bivalves). The author speculates that this might result from the trace components being associated with detritus particles and ingested by deposit feeders. The deposit feeders analysed have a life span of several years, and the reduction in heavy metal concentrations recorded one year after dredging was discontinued may be due to a new generation incorporated in the analysis. This would also explain the slow reduction found in the filter feeding oysters and blue mussels, the analysed specimens of which were several years old.

One-and-a-half years after termination of dredging, the benthic community structure was nearly restored and the high concentrations of heavy metals had decreased considerably.

Activity: dredging.

Impact: change in level of dissolved oxygen, nitrogen; change in levels of heavy metals.

Rosenberg, D. M., and N. B. Snow. 1975. Ecological studies of aquatic organisms in the Mackenzie and Porcupine river drainages in relation to sedimentation. Fish. Mar. Ser. Res. Dev. Tech. Rept. 547. 86 pp. (ADF&G, Habitat Library, #B5059.)

A review of literature on the effects of increased sedimentation on aquatic biota is presented. Specific detrimental effects, due to a variety of watershed disturbances, on flora and fauna are discussed. Recovery rates of flowing waters from increased sedimentation vary from a few days to not at all and depend, basically, on the characteristics of the river or stream, the quantity and duration of sediment addition, and the availability of undamaged areas as sources of recolonization. The reviewed literature indicates that unnatural increases in suspended sediment concentrations of most flowing waters should not result in a concentration greater than 80 mg/l to ensure protection of aquatic life.

Crossings of the Martin River by the Mackenzie Highway right-of-way slash, winter road, and temporary bridge resulted in no significant effects on benthic invertebrate and fish populations nor on the physical and chemical parameters of the water. The Dempster Highway crossing of Campbell Creek, N.W.T. (using a culvert), prevented upstream migration of northern pike and broad whitefish during the spring season. From visual observations, it appears the site has received an increased sediment supply, likely from roadfill and erosion of adjacent disturbed terrain. The physical and chemical parameters of the water showed no major differences. (Author's abstract: modified)

Activity: grading/plowing; stream crossing - structures.

Impact: change in turbidity or suspended sediments; addition of substrate materials; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen.

Rosenberg, D.M., and A.P. Wiens. 1976. Community and species responses of Chironomidae (Diptera) to contamination of fresh waters by crude oil and petroleum product, with special reference to the Trail River, Northwest Territories. J. Fish. Res. Bd. Can. 33:1955-1963. (ADF&G, Habitat Library, #R1507.)

On artificial substrates (baskets containing 30-35 stones ranging in size from 5 to 8 cm) saturated with crude oil and immersed in the Trail River, 10 species of Chironomidae showed a positive response to the presence of oil, 9 species showed a negative response, and 10 species were apparently unaffected.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons; artificial attractant to biological organisms.

Rothacher, J. 1970. Increases in water yield following clear-cut logging in the Pacific Northwest. Water Resour. Res. 6(2):653-658. (ADF&G, Habitat Library, #R3834.)

Increases in water yield following timber harvest roughly conform to the proportion of the area cleared. In high precipitation areas of the Oregon Cascades, clear-cut logging can increase annual water yield 18 in. Approximately 80% of the increase occurs during the October to March season. (Author's abstract)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water.

Rozengurt, M.A., and M.J. Herz. 1981. Water, water, everywhere but just so much to drink. Oceans 14:65-67. (ADF&G, Habitat Library, #R0722.)

The authors of this paper discuss water withdrawals from estuary systems. They describe the importance of estuaries in the environment and identify how estuaries often are affected when quantities of water are withdrawn from them. Past experience indicates that reductions in river flow may severely threaten fish and other resources in the estuaries receiving the flow. Several major estuaries (worldwide) are identified as examples of systems damaged due to reduction of river flow.

Conclusions drawn by the authors were as follows: 1) all hydrologic processes in estuaries depend upon fresh water outflow and sediment loads; 2) decreased fresh water runoff, reductions exceeding 30% of the original flow, lead to increased effects of ocean processes (winds, tides, currents) on the estuary through devastating increases in salt intrusion and salinification of the underground basins, flood plain and the destruction of levees; 3) increased light penetration resulting from reduced silt loads produces increased eutrophication and decreases dissolved oxygen (this is aggravated by nutrients from sewage and agricultural runoff); 4) effects of pollutants increase in the absence of sufficient fresh water for adequate dilution; and 5) all of these factors result in marked reduction in biological productivity and massive decreases in landings of fish and shellfish.

Activity: sewage disposal; water regulation/withdrawal/irrigation.

Impact: change in turbidity or suspended sediments; change in level of dissolved oxygen, nitrogen; change in level of salinity; change in levels of nutrients.

Ruth, R.H., and A.S. Harris. 1975. Forest residues in hemlock-spruce forests of the Pacific northwest and Alaska--a state-of-the-art knowledge review with recommendations for residue management. USDA: Forest Service Gen. Tech. Rept. PNW-39. 52 pp. (ADF&G, Habitat Library, #B3798.)

This report provides a detailed look at residue management throughout the North Pacific coastal fog belt, including Oregon, Washington, British Columbia, and Alaska. The approach is a general look at forest residues as part of the ecosystem, then a closer look at dead and decaying material after logging, considering fire hazard and the silvicultural, physical, chemical, and esthetic effects of this material. Residue treatments are described, evaluated, and recommended. The report is intended to provide an improved scientific framework for management decisions.

Hemlock-spruce residue volumes may range up to 250 t/a (560 mt/ha) when an old-growth timber stand is defective and has a high proportion of western red cedar, but volumes may be less than 50 t/a (112 mt/ha) with more complete utilization of sound young timber. The trend is to less residue volume as defective timber is replaced by vigorous young stands and utilization improves.

Residues often dominate the postlogging environment and are a major factor influencing forest regeneration. Fresh residue intercepts natural seed fall or aerially sown seed and prevents seedling establishment; but later, as it decays and with moisture present, it becomes a suitable seed bed for hemlock and spruce. Advance regeneration, usually hemlock, grow on decaying residue material and almost invariably is intermixed with fresh logging residue. Its fate is determined by residue treatment. When residue treatments expose mineral soil, they influence species composition favoring seral species. These ecological relationships between forest residues and conifer seedlings can be used by forest managers to influence density and species composition of the new timber stand. A common problem in hemlock-spruce is too many seedlings. When advance regeneration is prolific, harvesting plans and residue treatments should be designed to destroy some of the seedlings. Overstocking with postlogging regeneration can be reduced if the logging operation is planned so that fresh slash covers an appropriate portion of suitable seed beds.

In special situations, individual factors carry heavy weight in residue management decisions. For soils with high erosion potential, a protective mantle of organic material should be left. At least the small residue material should be left on nutrient-deficient soils to add to the nutrient capital. Residue should be kept out of stream channels. (Author's summary: partially modified)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; addition of physical barriers - partial obstructions.

Salo, E.O., N.J. Box, T.E. Prinslow, C.J. Whitmus, B.P. Snyder, and C.A. Simenstad. 1980. The effects of construction of naval facilities on the outmigration of juvenile salmonids from Hood Canal, Washington. Univ. Washington, Fish. Res. Inst., FRI-VW-8006. 159 pp. (ADF&G, Habitat Library, #B6200.)

The U.S. Navy expanded its facilities on Hood Canal, Washington, to serve as the support base for the Trident submarine. Shoreline construction consisted of building a drydock and five offshore piers with access trestles to each pier. Pier construction work was continuous and included the season of out-migration of juvenile salmonids (January through July). This 5-yr study was divided into four components: 1) the Out-migration Study, which included the effects of piers on the migration and feeding behavior of young salmon; 2) the Lighting Study, which included the effects of security lighting systems at the piers on the behavior of salmonids and other fishes; 3) the Dredging Study, which included the effects of suspended sediments caused by the dredging of 171,000 m^3 of bottom sediments (recent alluvium and glacial till) on juvenile salmonids; and 4) the Food Habits Study, which investigated the feeding habits of young salmon in the areas of concern as well as in control areas.

The Out-migration Study examined five seasons of out-migration using beach seines and townet surveys to measure abundance and migration pathways of the juvenile salmonids. Chum salmon, Oncorhynchus keta, the prevalent salmonid species - and one of the more sensitive to environmental changes in nearshore environs - varied in abundance from year to year. The variations among the years were not related to the numbers released annually from the hatcheries, although within any year the variation in abundance was closely related to hatchery releases. This suggests large but differing early marine mortality rates from year to year. The migration routes were defined, and comparisons were made of the numbers migrating along the west shore and those migrating along the east shore, the site of the support base. There is an indication that the juvenile chum move offshore around the wharves as they migrate north out of the Canal. The effects of this diversion are not known, although from 1976 to 1979 there was a decrease in the relative number of migrants on the east shore migrating past an index area north of the base. This trend was not found with catches south of the base (on the east shore) nor with catches on the west shore. Also, in 1977 and 1978, there was a decrease in abundance in an index area adjacent to the construction site of the Delta Pier. This decrease appears to be temporary as the catch increased in 1979. Although the evidence is circumstantial, these changes in migratory behavior and reduction in catch appear to be related to the construction and operation of the piers. Without a more extensive data base with which to quantify increases in natural mortality rates due to natural environmental fluctuations, we still remain uncertain as to the significance of these perturbations.

The Dredging Study showed that concentrations of suspended sediments experienced by migrating salmonids at the Delta Pier site (less than 100 mg/l) did not approach lethal levels nor was any overt stress indicated. Instances of avoidance of suspended glacial till material at low concentrations (2-10 mg/l above ambient) were noted in the field, while in the laboratory, avoidance was not shown until a concentration of 182 mg/l was reached.

The Lighting Study showed that the operational mode of lighting (20-40 ft-c at water surface) at the Explosives Handling Wharf (EHW) may attract out-migrating salmonids, while the security lighting mode (0.2 - 1.2 ft-c at water surface) may be an attractive stimulus only within a localized (5-10 m) zone of the wharf. The effect appears to be temporary (less than 24 h). The operational mode may serve as an initial stimulus which, when combined with the abundance of food near the EHW, may cause a 1-2 d delay in the out-migration of chum. The security mode did not appear to cause any delay in the out-migration. Any attraction to the EHW does not appear to harm the out-migrating salmon, as less than 4% of the predators caught during the study of security mode lighting contained salmonid remains. We suggest that pier lighting be kept at levels equivalent to the security mode as much as possible.

The Food Habits Study showed that abundance of ephibenthic organisms preferred by chum and pink salmon, principally the harpacticoid copepods, showed a decline in spring coincidental with the peak densities of chum salmon fry. Chum fry appear to select the larger available organisms when feeding both in nearshore and offshore waters. The long-term effects of construction and operation of the shore facilities upon the prey (fish food) communities are expected to be minimal as long as extensive areas of littoral eelgrass habitat are not destroyed. (Author's abstract: modified)

Activity: dredging; filling (aquatic and wetland habitats).

Impact: change in turbidity or suspended sediments; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - diversions; addition of physical barriers - partial obstructions; artificial attractant to biological organisms.

Saskatchewan Department of the Environment. 1981. Guidelines for-environmental protection during road development. Saskatchewan Department of the Environment. Unpubl. document. 52 pp. (ADF&G, Habitat Library, #R2828.)

The Saskatchewan Department of the Environment assembled an assortment of guidelines and considerations into this document to provide standards for the construction of roads in that province. These considerations have direct application to road development and construction in Alaska and should prove invaluable.

Guidelines and considerations cover every aspect of road construction: route selection, survey, design, construction, reclamation, maintenance, and decommissioning and abandonment.

Activity: grading/plowing; stream crossing - structures.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; addition of physical barriers - partial obstructions.

Saunders, J.W., and M.W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Trans. Am. Fish. Soc. 91:185-188. (ADF&G, Habitat Library, #R5107.)

Thirteen dams, 12 deflectors, and several covers were constructed in a 450-yd section of Hayes Brook, Prince Edward Island, to create suitable hiding places for brook trout, <u>Salvelinus fontinalis</u> (Mitchell). In the following year, the standing crop of fingerlings (age o) was above average. The numbers of age 1 and older trout were approximately doubled. The alterations had no noticeable effect on the growth of trout. (Authors' abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Sawaragi, T., and K. Kobune. 1970. Effect of jetties on water level at a river mouth. Coastal Engineer. in Japan 13:153-159. (ADF&G, Habitat Library, #R3876.)

This paper presents a laboratory study on water level fluctuation with respect to the change of lengths and opening area of jetties. The model simulates a situation in which a pair of jetties were placed at a river mouth to prevent the buildup of sand. The authors assume that the water level fluctuation is caused by the interaction between river effluence and waves and accordingly present this fluctuation as the sum of separable fluctuations of the effluence and waves. The following results are reported: 1) when the jetties have short lengths, they do not have so much effect on causing the decrease of water level and they sometimes cause the rise of water level, and 2) when the jetties exceed some limit in length, they have the effect of causing the decrease of water level. With this information, the authors assertain that reasonable planning for the construction of jetties is possible, based on analytical studies involving specific site characteristics. (Authors' abstract: modified)

Activity: filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Sayce, C.S., and D.F. Tufts. 1972. The effect of high water temperature on the razor clam, Siliqua patula. (Dixon). Proc. Nat. Shellfisheries Assoc. 62:31-34. (ADF&G, Habitat Library, #R3903.)

Adult razor clams from an open beach in Washington state were exposed to warmed sea water for 1, 2, 3, and 4 h and then returned to ambient seawater in laboratory experiments. Mortalities began after 4 h exposure to sea water 10°C above ambient temperatures, which ranged from 5.0 to 11.6°C. Fifty-percent mortality was reached at a temperature of 11.2°C above ambient after 4 h exposure, 14.1°C above ambient after 3 h exposure, 14.3°C above ambient after 2 h exposure, and 14.8°C above ambient after 1 h exposure.

The most obvious thermal effects on the clams were debilitated muscles, which were unresponsive when subjected to mechancial stimuli, and extensive mantle separation from the shell, which occurred in all cases of mortality. The degree of mantle separation that may be tolerated by the razor clam was not investigated, and the authors recommend further study of that effect.

Activity: sewage disposal.

Impact: change in water temperature.

Schaumburg, F.D. 1973. The influence of log handling on water quality. EPA. Environmental Protection Technology Series. EPA-R2-73-085. 105 pp. (ADF&G, Habitat Library, #R4269.)

In these studies, the character and quantity of leachate from douglas fir, ponderosa pine, and hemlock logs were examined. Measurements including BOD, COD, PBI, solids, and toxicity showed that in most situations the contribution of soluble leachates to holding water is not a significant water pollution problem. The author concluded that the most significant problem associated with water storage appears to be the loss of bark from logs during dumping, raft transport, and raft storage. Floating bark is aesthetically displeasing and could interfere with other beneficial uses of a lake, stream, or estuary. Benthic deposits exert a small but measureable oxygen demand and may influence the biology of the benthic zone. Methods are suggested for reduction of bark loss in the aquatic environment.

Activity: log storage/transport.

Impact: addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates; change in levels of nutrients.

Schlosser, I.J. 1982. Trophic structures, reproductive success, and growth rate of fishes in a natural and modified headwater stream. Can. J. Fish. Aquat. Sci. 39:968-978. (ADF&G, Habitat Library, #R5108.)

The impact of removing riparian vegetations, channel straightening, and flucutations in flow regime on trophic structure, reproductive success, and growth rate of fishes was assessed in a natural (Jordon Creek (JC)) and modified (Big Ditch (BD)) headwater stream in east central Illinois. Shallow habitats and organic substrates increased more in the modified stream than the unmodified stream during low flow periods in summer. Insect densities in the unmodified stream were predominantly benthic insectivores and insectivore-piscivores; trophic structure, age structure, and biomass were stable between years and seasons; recruits made up a small and stable portion of community biomass and were primarily insectivore-piscivores and generalized insectivores; younger age-classes were in shallow riffle habitats. Adult fish and recruits in the modified stream were predominantly generalized insectivores, omnivores, and herbivore-detritivores; the last two were primarily mid-river species (Carpoides cyprinus and Dorosoma cepedianum). Considerable seasonal and annual variation in trophic structure, total biomass, and age structure occurred in BD associated with annual fluctuations in flow regime, abundance of organic substrates, and reproductive success of mid-river species. Younger age-classes had higher summer growth rates in the modified stream. The temporally variable physical environment and unstable autotrophic energy base created in modified headwater streams are probably major factors responsible for recent shifts in large river fish communities in the midwestern United States from insectivore and insectivore-piscivore species to omnivores and herbivore-detritivores. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; alteration of natural cover - riparian vegetation; introduction or removal of species.

Schmal, R.N., and D.F. Sanders. 1978. Effects of stream channelization on aquatic macroinvertebrates, Buena Vista Marsh, Portage County, Wisconsin. USDI: USFWS. FWS/OBS-78/92. 80 pp. (ADF&G, Habitat Library, #B1988.)

The objectives of this study were to assess the effects of channelization on density and biomass of benthic and drifting macroinvertebrates, amount of drifting seston, and water temperature and chemistry in the Buena Vista Marsh, Wisconsin. One-hundred-meter sections of newly channelized (6-8 yr old) and old channelized (52-62 yr old) ditches and natural control streams from both upstream and downstream areas of the marsh were sampled between June 1974 and May 1975 and July 1975 and May 1976 at about 6-wk intervals during ice-free periods.

Substrate strongly influenced macroinvertebrate populations. Mean benthic density and biomass (excluding molluscs) from upstream and downstream areas were positively curvilinearly related to percentages of productive substrates ($r = 0.89$ and 0.69, respectively). Productive substrates, i.e., vegetation, silt detritus, and gravel, apparently provided interstices for entrapment of drifting seston resulting in negative relationships between seston and substrate ($r = 0.76$ and -0.87 for upstream and downstream sites, respectively). Productive substrates, discharge, drifting seston, and benthic populations together accounted for as much as 67% of the variation observed in drifting invertebrate density.

Channelization affected macroinvertebrate populations by creating unstable substrate conditions during spring high flows but created favorable vegetation and silt-detritus substrates as spring flows subsided and substrates stabilized. When vegetation and silt-detritus were predominant, invertebrate populations were high; when substrate was largely shifting sand and unstable silt-detritus, invertebrate populations were low. Newly channelized sites had higher benthic biomass and density than old ditches and natural streams except during unstable substrate conditions. The vegetation and silt-detritus in the ditches were favorable to snails (Gastropoda: Mollusca) and midges (Diptera: Chironomidae). Gastropods accounted for as much as 97% of mean benthic biomass in the upstream new ditch and Chronomidae up to 89% of mean benthic density in the downstream new ditch. More invertebrate taxa were collected from natural streams, but differences were not statistically significant. However, stoneflies (Plecoptera) were only collected from natural streams, and more genera of mayflies (Ephemeroptera) and caddisflies (Trichoptera) were collected only from natural streams than from ditches.

Channelized areas, with the exception of the downstream new ditch, generally were devoid of depositional areas such as pools and point bars. The resulting reduced diversity of habitats in the ditches, especially during spoil bank instability and high spring flows, may have increased the amount of drifting seston when the more productive substrates were not present or not stable. Changes in amount of drifting seston at all sites seemed to correspond to changes in productive substrates and water level fluctuations.

Channelization appeared to affect invertebrate drift through its influence on drifting seston and benthos. Increases in invertebrate drift upstream, especially Chironomidae, corresponded to increases in amount of seston ($r = 0.71$). Drift density at all sites downstream was significantly related to benthos density ($r = 0.74$). Numbers of drifting taxa were highest at sites with the highest percentages of sand substrate in their respective areas, the upstream old ditch and downstream natural stream. The downstream natural stream, despite low numbers of benthic taxa due to a predominatly shifting sand bottom, had significantly more invertebrate taxa in the drift than the downstream ditches.

Water temperature and chemistry did not differ greatly amoung the natural streams and ditches, which receive approximately 90% of their flow from groundwater. However, water temperature was generally higher in the ditches than in natural streams. Increases in water temperature in the ditches may have resulted from removal of bank shading and slowing of flow. Water temperature exceeded 25°C (the 133-h upper lethal temperature for brook trout, Salvelinus fontinalis) for five consecutive days in the downstream new ditch in 1975. New and old channelized areas had higher alkalinity and total and calcium hardness than the natural streams. (Authors' summary)

Activity: channelizing waterways.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; change in levels of pH, alkalinity, or hardness; introduction or removal of species.

Schmiege, D.C. 1980. Processing mills and camps. Vol. 11 <u>in</u> W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in Western North America. Series: 1979-. USDA: Forest Service. Pacific Northwest Forest and Range Experiment Station, Portland, OR. Gen. Tech. Rept. PNW-113, Vol. 11. 17 pp. (ADF&G, Habitat Library, #B2439.)

This is a general summary of the effects of effluents from pulp and paper mills on fish and other aquatic animals in the marine and freshwater environment. It includes sections on toxicity of effluents, increased oxygen demand, suspended settleable materials, and air pollution. It also includes a section on the effects of development and use of logging camps.

The known sublethal effects of pulp and paper efflucents are attributable to coniferous fibers, hydrogen sulfide, and nonvolatile soluble toxic substances. The last group is of major environmental concern. Effects displayed by fish after exposure to lethal concentrations of kraft effluent include loss of schooling, respiratory distress, abnormal gill movements, reluctance to eat, loss of equilibrium, convulsive coughing, excessive mucous production, and finally death.

Activity: human disturbance; processing lumber/kraft/pulp.

Impact: addition of substrate materials; increase in hydrostatic pressure or noise; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates; change in levels of other toxic compounds - other.

Schoof, R. 1980. Environmental impact of channel modification. Water Resour. Bull. 16(4):697-701. (ADF&G, Habitat Library, #R3844.)

The purpose of this literature review is to identify and quantify the effects of channelization and to examine the feasibility and acceptability of alternative methods of flood control. In the past 150 yr, over 200,000 mi of stream channels have been modified. Channelization can affect the environment by draining wetland, cutting off oxbows and meanders, clearing floodplain hardwoods, lowering ground water levels, reducing ground water recharge from stream flow, and increasing erosion sedimentation, channel maintenance, and downstream flooding. Channelization reduces the size, number, and species diversity of fish in streams, In a wet climate, the fishery requires less than 10 yr to fully recover. However, in the drier climates, the fishery may never fully recover. In general, channel modifications have performed as designed for flood abatement. Diking seems to be a viable alternative to channel dredging. Dikes minimize destruction of wetland and eliminate the need for removing vegetation from the existing stream banks. (Author's abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; introduction or removal of species.

Schultz, R.D., and R.J. Berg. 1976. Some effects of log dumping-on estuaries. USDC: NOAA, NMFS, Environmental Assessment Division, Juneau, AK. 65 pp. (ADF&G, Habitat Library, #B6357.)

Biologists investigated 32 log transfer sites in Southeast Alaska to determine persistence of bark accumulation in estuaries and its effects on estuarine life. Nineteen sites had bark accumulation, which ranged from a trace to 26 cm. Numbers of flora and nonmotile benthic invertebrate species were significantly lower in occurrence at log transfer sites than at control sites. Recommendations are made for siting log transfer facilities in estuaries.

Addition of bark as substrate resulted in a reduction in the abundance of existing plant life due to direct smothering and prevention of repopulation presumably due to the instability of the bark substrate. Smothering of sessile animals also occurred, whereas mobile animals apparently were able to vacate the deposit zones. On the other hand, some sessile forms were able to repopulate the bark deposits. For example, the anemone Metridium senile and tunicate Corella spp. were successful colonizers, as were king crabs (Paralithodes camtschatica), Dungeness crab (Cancer magister), starfish, cod (Gadus spp.), and shiney sea perch (Cymatogaster aggregata). The extent to which these colonizing species were "benefitted" was not determined.

Activity: log storage/transport.

Impact: addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates.

Schuytema, G.S., and R.D. Shankland. 1976. Effects of log handling and storage on water quality. EPA, Cincinnati, OH. Rept. No. EPA-600/2-76-262. 75 pp. (ADF&G, Habitat Library, #B4552.)

The biological and chemical effects of three types of log storage on water quality were investigated. Three flow-through log ponds, two wet deck operations, and five log-rafting areas were studied. Both biological and chemical aspects of stream quality can be adversely affected by flow-through log ponds and runoff from wet decks. Severity of degradation varies widely with each situation. Runoff from wet decks had pollution characteristics equal to or greater than that of the waters from the flow-through log ponds studied.

Esthetically, a stream can be affected by the dark color of the water coming from a log pond or wet deck. Floating bark from a log raft or a log pond is also aesthetically displeasing. The most significant problem associated with log rafting is the loss of bark that commonly occurs when the logs are dumped into the water.

The authors conclude:

1. Dissolved oxygen in flow-through log ponds tends to become depleted during summer months when flows are low and the waters are warm.
2. Both biological and chemical aspects of water quality can be adversely affected by flow-through log ponds.
3. The discharge from flow-through log ponds is esthetically displeasing, due mainly to the dark color of the water. This dark color persists downstream until it is diluted out.
4. The runoff from wet decks has pollutional characteristics equal to or greater than that of waters from flow-through log ponds.
5. Although wet deck runoff has the potential to degrade water quality in a receiving stream, especially under low flow conditions, this effect could not be directly demonstrated.
6. The effects of handling and rafting logs on water quality in rivers and sloughs depends on the intensity of such activity and the stream's flushing action. A significant problem associated with water storage is the loss of bark during log dumping. Degradation will tend to be greater when larger amounts of logs are handled and rafted. Flushing action of the stream may reduce degradation or even transfer the problem to another area.

Activity: log storage/transport.

Impact: addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates.

Schwan, M., S. Elliott, and J. Edgington. 1985. The impacts of clearcut logging on the fisheries resources of Southeast Alaska. Pages 59-95 in M.J. Sigman, ed., Part II, Impacts of clearcut logging on the fish and wildlife resources of Southeast Alaska. ADF&G, Div. Habitat, Tech. Rept. 85-3, Juneau. (ADF&G, Habitat Library, #B6565.)

This is a review paper of the most recent scientific investigations being conducted in southeast Alaska on the effects of logging on fish. A summary of the more pertinent findings includes the following:

Streamflow:

1) Streamflow generally increases after logging. Variations in streamflow between watersheds after logging appears to be due to the amount of area harvested and the amount of roads. Potential effects of increased streamflows include
   - an increase in the amount of rearing area and an increase in the production of rearing salmonids,
   - increased bank erosion and sedimentation causing lower egg-fry survival,
   - and exacerbation of sedimentation by shifting of destabilized woody debris.
2) Second growth may cause a reduction in streamflow relative to prelogging flow regimes. Potential effects of decreased flows include
   - a reduction in rearing salmonid carrying capacity by a reduction in rearing area,
   - warmer water temperatures, although this may be offset by improved shading,
   - and an increase in the frequency of adult "die-offs" during mid-summer drought conditions.

Temperature:

1) Temperature increases in proportion to the amount of stream-side canopy removal. Temperature should revert to normal regimes when second- growth canopy develops to a height capable of shading the stream.
2) Increased temperature can persist through the winter and shorten the development time of incubating salmon eggs and alevins, causing earlier emergence. Early emerging pink and chum salmon fry may enter the estuary prior to spring blooms of marine plankton and experience a food shortage. Early emerging coho and other rearing species enter streams at a time when floods are more common and may be swept downstream and lost to the system, causing reduced rearing density. Elevated primary productivity and a longer growing season result in higher growth rates and larger fish. Larger fish can have greater summer and winter survival rates, in some streams, yielding more smolts of a larger size, which increases the adult return. These effects are short-lived, however, as second growth should reduce temperatures to prelogging levels 15-20 yr after cutting.

3) The timing of pink salmon runs is correlated with stream temperature. Changes in watershed temperature could inhibit upstream migration of adult pink, chum, and coho salmon.

Sedimentation:

1) Sedimentation can increase over natural levels as a result of catastrophic incidences attributable to human error, poor planning, or improper design and layout.

   Streamside logging leads to gradual, but accelerating, changes in stream morphology with increasing rates of sedimentation and bedload movement. Chronic sedimentation can occur as a result of increased streamflow and accelerated erosion, bank destruction, destabilization of mid-stream woody debris, destabilization or loss of debris that anchors streambanks, and the death of tree roots that support or strengthen streambanks. Potential effects of sedimentation include the following:

   - Sedimentation can cause a decrease in egg-to-fry survival of salmonids -- intense pulses of sediment affecting rearing salmonid behavior and decreasing feeding and growth rate.
   - A reduction of benthos diversity and abundance can occur, causing changes in fish food supplies.

2) If sources of sedimentation are arrested, most fines are flushed from the system during freshets and are usually removed within 1 yr.

Light levels and nutrients:

1) Solar penetration increases with timber canopy removal and, in conjunction with increased temperature and nutrients, leads to increased primary production, elevated benthos production, and (where nutrients are abundant) increases the density of coho fry during the summer.
2) Changes in stream productivity are presumed to be, in part, responsible for higher growth rates and earlier smolt age of juvenile coho. Increased production in some studies has been nullified by the winter carrying capacity, which is regulated by the amount of winter habitat.

Stream habitat structures:

1) In coastal forest streams, habitat is formed by the influence of streambank conifers and the introduction and incorporation of large woody debris. Woody debris and the low-velocity conditions it creates are essential for optimum rearing production.
2) Logging can overload streams with introduced debris. In large streams, debris is transported downstream where it can dislodge natural accumulations and cause channel modification and sedimentation. Debris in large streams generally does not create barriers to upstream migrants because streams scour passages under or around large jams.
3) In small streams, debris remains in place. Fresh green material can potentially cause a decrease in dissolved

oxygen, and its leachates can create conditions toxic to fish. Slash in small streams is dense and interlocked and can create barriers to upstream migrating adult fish.

4) Dense logging debris loses most of its leachates after 1 yr and does not constitute a water quality problem thereafter. Dense accumulations do not inhibit rearing salmonid production; in some cases, production may actually be increased by providing greater amounts of cover.
5) Overzealous clearance of logging slash often removes natural as well as introduced material. Removal of too much debris deprives juveniles of cover, and salmon populations can be seriously reduced during fall freshets. Populations will remain unstable until stream habitat is rehabilitated.
6) Loss or destabilization of mid-stream woody debris, disturbance of debris that anchors stream banks, or death of tree roots that support bank structures can reduce the amount of high-quality rearing habitat. This reduces summer and winter carrying capacity and may affect smolt yield. Losses in smolt yield resulting from habitat degradation may nullify increases in summer productivity or, in conjunction with severe winters, may cause a net loss of smolt relative to prelogging levels.
7) Long-term effects on habitat quality may result from stream destabilization, as observed in Carnation Creek, British Columbia, and from lack of recruitment of woody debris upon removal of streamside timber. Data suggest a 30-50% decrease in carrying capacity occurring 80 yr after initial cutting of streamside conifers.

Recommendations:

1) Stream protection and mitigation techniques should be applied during logging as the key to preserving the productive capacity of streams over the short and long term. The two most promising techniques are buffer strips and debris management. Design criteria need to be determined through applied research before maximum benefit cna be gained from their use.
2) Further research should be conducted
   a) to determine if changes in winter temperature regimes occur in Southeast Alaska as a result of timber harvest and how temperature changes affect salmonid stocks,
   b) to determine the extent and severity of streamside destabilization caused by logging and how salmonid stocks are affected, and
   c) to correlate intergravel waterflows to fry survival.
3) Stringent guidelines should be implemented to minimize the addition of sediment to streams from logging-related activities.

(Executive summary)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions; change in levels of pH, alkalinity, or hardness; change in levels of other toxic compounds - bark or log leachates; change in levels of nutrients.

Scrivener, J.C., and B.C. Andersen. 1984. Logging impacts and some mechanisms that determine the size of spring and summer populations of coho salmon fry (Oncorhynchus kisutch) in Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 41:1097-1105. (ADF&G, Habitat Library, #R3644.)

Natural patterns in emergence times, seaward movements, instream distributions, densities, and growth of coho salmon fry between March and September are contrasted with patterns observed during and after logging in the Carnation Creek watershed. After streamside logging in 1976-1977, fry emerged up to 6 wk earlier and moved seaward more quickly than prior to logging. These observations are attributed to higher water temperatures during the winter and to emergence during a period of more frequent freshets. Increased fry movement from the stream could result in habitat being underutilized. In sections affected by intense streamside logging, the deposition of "fine" logging debris led to increased fry densities during the summers of 1977 and 1978. After major freshets in November 1978, which removed this fine debris and affected channel morphology in these sections, fry densities declined below those observed prior to logging. The growth rate of fry was inversely correlated with density in all stream sections. Growth rates, after correction for density, tended to be greater in all sections after the adjacent streamside was logged. Large fry and more variable numbers of fry remained in the stream in September after logging than before logging. Their increased size is attributed to the longer growing season afforded by earlier emergence. This complex of interacting factors determines the number and size of fry in autumn and it can influence the production of smolts the following spring. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in water temperature; addition of substrate materials.

Scrivener, J.C., and M.J. Brownlee. 1982. An analysis of the Carnation Creek gravel-quality data 1973-1981. Pages 154-173 <u>in</u> G. Hartman, ed. Proceedings of the Carnation Creek workshop, a 10 year review. Pac. Biol. Sta., Nanaimo, B.C. (ADF&G, Habitat Library, #R3003.)

A project to study the effects of logging on a small salmonid nursery stream commenced in 1970 at Carnation Creek on the west coast of Vancouver Island, British Columbia. The project is designed for 5 yr of prelogging calibration (1970-1975), 6 yr of logging (1975 - 1981), and five years of postlogging assessment (1981-1986). A component study of this multidisciplinary project is the assessment of spawning gravel quality. More than 1,200 gravel cores, intergravel-dissolved oxygen, and intergravel permeabilities have been obtained since 1973 to assess changes in the quality of the gravel and the corresponding changes to survival and condition of salmon embryos. Cores were split and analyzed as three layers. Fines less than 9.55 mm were found to increase with depth. A seasonal trend was exhibited in the top and middle layers, as particles less than 0.297 mm decrease between early autumn and the following spring. After logging commenced, fines less than 9.55 mm increased in the top layer over prelogging levels. Major accumulations of particles between 9.55 mm and 0.297 mm occurred in the top layer of the lower 2 km of stream after the first major postlogging freshet. Concurrently, fines decreased in the bottom layer and intergravel permeability, and dissolved oxygen declined. The addition of data from August 1980 to September 1981 indicated that all classes of fines were still accumulating in the streambed. Marked reductions in chum and coho salmon egg-to-fry survival were noted. All studies are continuing until project completion. (Authors' abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in level of dissolved oxygen, nitrogen.

Sedlak, J.P. 1982. A comparison of the rafting and barging of logs in southeast Alaska. USDA: Forest Service, Alaska Region Admin. Doc. No. 118. 115 pp. (ADF&G, Habitat Library, #B1082.)

This report contains a short but useful survey of recent literature on environmental impacts of rafting and barging of logs on the marine environment. It also includes a tabular summary of log handling impacts and a brief narrative that discusses ways of lessening such impacts. The state of Oregon's policy for log handling is listed in an appendix to this report.

Activity: log storage/transport.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates.

Seelye, J.G., Hesselberg, R.J., and M.J. Mac. 1982. Accumulation by fish of contaminants released from dredged sediments. Environmental Science and Technology 16(8):459-464. (ADF&G, Habitat Library, #R3809.)

Dredging and disposing of dredged materials causes a resuspension and availability of contaminated materials to organisms. A series of experiments were conducted to examine the potential accumulation by fish of contaminants from suspended sediments. Fish exposed to nonaerated sediments for 10 d (a period which the authors felt resonable to duplicate dredging operations) accumulated PCBs (polychlorinated biphenyls) and Hg (mercury), while fish exposed to aerated sediments for the same amount of time accumulated PCBs, DDE, Zn (zinc), Fe (iron), Cs (cesium), and Se (selenium).

These results demonstrate that several common environmental contaminants can be accumulated by fish directly from resuspended sediments.

Activity: dredging; solid waste disposal.

Impact: change in levels of heavy metals; change in levels of other toxic compounds - other.

Sekerah, A., and M. Foy. 1978. Acute lethal toxicity of Corexit-9527/Prudoe Bay crude oil mixtures to selected arctic invertebrates. Spill Technology Newsletter 3(2):37-41. (ADF&G, Habitat Library, #R3181.)

Four arctic marine invertebrates (amphipods: <u>Onisimus</u> <u>litoralis</u>, <u>Boeckosimus</u> <u>edwardsi</u>, <u>Anonyx</u> <u>nugax</u>, and a copepod <u>Calanus</u> <u>hyperboreus</u>) were exposed to Prudhoe Bay crude oil and Prudhoe Bay crude oil/Corexit 9527 dispersant mixtures (10:1, by volume). A summary of the results of this study are provided below, taken directly from the report. Values in the table are median lethal concentrations (96 h LC_{50}s). On the basis of amount of oil added, greater mortality was observed in the Corexit-dispersed oil-water mixtures. This was not thought to be due to the toxicity of Corexit because no mortalities were observed in Corexit concentrations up to the maximum used in oil/Corexit mixtures in tests on two species. It is speculated that a greater proportion of nontoxic hydrocarbons were dispersed in the water column by using Corexit.

Table 1. Median Lethal Concentrations (96h LC_{50}) Based on Measured Hydrocarbon Concentrations

Test Organism	SLS[a]	Prudhoe Bay Crude	Corexit 9527	Prudhoe Bay Crude Corexit 9527
<u>Onisimus</u> <u>litoralis</u> 7 to 13 mm length 1 yr old	4-40	49 (44-55)[b]	70	24-213
<u>Boeckosimus</u> <u>edwardsi</u> 6 to 15 mm length 1 yr old?	40	44 (43-45)	80	64-213
<u>Anonyx</u> <u>nugax</u> 23 to 42 mm length 3 size classes	26(20-32)	38 (32-43)	---	64-213
<u>Calanus</u> <u>hyperboreus</u> mostly copepodite stages IV to VI (adult)	---	73 (51-103)	---	196 (161-238)

--- means no data were available.

a Sodium lauryl sulphate.

b Parenthetical figures represent 95% confidence limits.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Servizi, J.A., and J.O.T. Jensen. 1977. Resistance of adult sockeye salmon to acute thermal shock. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 34. New Westminster, B.C., Can. 11 pp. (ADF&G, Habitat Library, #B6195.)

The resistance of adult sockeye salmon (Oncorhynchus nerka) to acute thermal shock was measured under laboratory conditions using sockeye treated to resist infection. The upper lethal temperature due to acute themal shock was about 24°C for adult sockeye. A graph of geometric mean survival time (GMST) versus temperature was similar to that reported for juvenile sockeye but was displaced lower by 1 to 1.5°C, indicating that adults were less resistant to high temperatures. A discontinuity occurred at the upper end of the curve where a second mortality curve commenced associated with infections of Flexibacter columnaris.

Loss of equilibrium preceded death, with the difference in time between first loss of equilibrium and GMST decreasing as temperature increased. It was concluded that mortalities could be expected for thermal exposures exceeding the temperature-time relations for the loss-of-equilibrium curve. However, since temperatures lower than those causing death by thermal shcok are a factor in mortalities caused by F. columnaris, it was recommended that these lower levels take precedence when temperatures are specified for protection of sockeye. (Author's abstract/conclusions: partial)

Activity: clearing and tree harvest; grading/plowing; water regulation/withdrawal/irrigation.

Impact: change in water temperature.

Servizi, J.A., and D.W. Martens. 1974. Preliminary survey of toxicity of chlorinated sewage to sockeye and pink salmon. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 30. New Westminster, B.C., Can. 42 pp. (ADF&G, Habitat Library, #B6186.)

In situ bioassays were conducted using sockeye salmon (Oncvorhynchus nerka) and pink salmon (O. gorbuscha) to determine whether chlorinated sewage created toxic conditions in the vicinity of sewage outfalls. Chlorination increased toxicity of sewage considerably, although effluents from primary and aerated lagoon treatment systems were lethal to salmon in the absence of chlorination. On the other hand, effluent from an activated sludge plant was not lethal after cechlorination by storage in a lagoon.

Histopathological examination indicated damage to gills was most severe and rapid among fish exposed to chlorinated effluents, whereas irritation was least among gills of fish exposed to secondary effluent dechlorinated in a lagoon.

Batch tests indicated chlorine residuals persisted at lethal levels for more than 2 d in sewage. In addition, comparison of orthotolidine and amperometric methods of measureing chlorine residual indicated the former was not sensitive enough to detect concentrations of chlorine that would be lethal. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of chlorinated compounds.

Servizi, J.A., and D.W. Martens. 1978. Effects of selected heavy metals on early life of sockeye and pink salmon. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 39. New Westminster, B.C., Can. 26 pp. (ADF&G, Habitat Library, #B6194.)

Sockeye and pink salmon were exposed continuously to cadmium, copper, and mercury under laboratory conditions during the egg to fry stage. Observations of mortality, hatching, development and growht were used to evaluate toxic effects. Acute toxicity was quantified by measurements of median tolerance limit using alevins, fry, and smolts.

Mortality, hatching, and growth of sockeye salmon during the egg-to-fry stage were not affected by continuous exposure to 5.7 ug/l cadmium. However, the 168-h LC_{50} for first feeding fry was 8 ug/l cadmium.

When exposed to copper, the incipient lethal level was between 37 and 78 for sockeye but between 25 and 55 ug/l for pink salmon during the egg-to-fry stage. Growth and hatching were no better than mortality as indicators of toxic effects of copper. Copper inhibited egg capsule softening, but asso- ciated mortalities during hatching occurred only at concentrations also lethal to eggs and alevins. Copper was concentrated by eggs, alevins, and fry in proportion to exposure concentrations. Copper concentrations of 105 and 6.8 ppm in pink salmon eyed eggs and fry, respectively, coincided with mortalities.

Continuous exposure of eggs to 2.5 ug/l mercury caused malformed embryos at hatching. Mortality, growth, and hatching were less sensitive to mercury than was malformation. Mercury was concentrated by sockeye and pink salmon in proportion to exposure concentration during the egg to fry stage. Mercury concentrations of 1.87 ppm in eyed eggs coincided with malformed embryos at hatching. (Author's abstract)

Activity: dredging; grading/plowing; processing minerals.

Impact: change in levels of heavy metals.

Servizi, J.A., D.W. Martens, and R.W. Gordon. 1970. Effects of decaying bark on incubating salmon eggs. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 24. New Westminister, B.C., Can. 28 pp. (ADF&G, Habitat Library, #B6182.)

The effect of bark contamination on salmon spawning grounds was assessed in laboratory tests on sockeye salmon (Oncorhynchus nerka) eggs and alevins. Bioassays showed that chemical toxicity of materials leached from bark of Douglas fir, lodgepole pine, Engelmann spruce, and Alpine fir was not a factor influencing survival under the conditions tested. However, abundant growths of the bacteria Sphaerotilus sp. occurred on bark during initial stages of decay, causing severe mortalities among sockeye eggs and alevins due to suffocation. In gravel-filled incubation boxes, contamination of gravel with bark caused significant reductions in survival from egg to fry at bark concentrations of 10% by volume, but 1% bark concentrations did not influence survival. It was estimated that bark concentrations of 4% and more were likely to increase egg-to-fry mortality owing to depletion of oxygen supplies at incubation velocities around 5 cm/h, whereas bark concentrations of 1% and greater might retard emergence timing, owing to oxygen depletion. However, calculated oxygen levels alone are insufficient criteria for estimating the effect of bark upon survival, because they fail to consider uneven distribution of water flow caused by bark contamination. Mortalities increased as bark concentraiton increased and as water flow decreased. Mortalities were attributed to blockage of intragravel water flow by bark particles. The oxygen demand of decaying bark was found to be relatively constant with time during the 683-d study. Calculations based on oxygen demand of bark indicated the amount of oxygen that would remain for egg incubation in natural redds at various temperatures and levels of bark contamination. Possible effects of various oxygen concentrations on size and emergence timing of fry were discussed and limiting amounts of bark recommended. (Author's abstract/con- clusions: partial)

Activity: log storage/transport.

Impact: change in levels of other toxic compounds - bark or log leachates.

Servizi, J.A., D.W. Martens, and R.W. Gordon. 1978. Acute toxicity at Annacis Island primary sewage treatment plant. Int. Pac. Salmon Fish. Comm. Prog. Rept. No. 38. New Westminster, B.C., Can. 12 pp. (ADF&G, Habitat Library, #B6189.)

Continuous flow and static bioassays of dechlorinated primary sewage were conducted at Annacis Island sewage treatment plant using fingerling sockeye salmon (Oncorhynchus nerka). Sewage consisted of a mixture of domestic, commercial, and industrial waste waters, plus stormwater during wet weather. Treatment included prechlorination, preaeration, sedimentation, disinfection by chlorination and dechlorination using sulphur dioxide. Geometric mean survival time (GMST) was determined using undiluted effluent and survival during 96-h exposure to a range of dilutions was measured. Acute toxicity was greater during continuous flow than during static bioassays. In addition, acute toxicity was greater during dry weather than during wet weather flow conditions. Mortalities occurred at 10% v/v.

Results were compared with acute toxicities measured at three other primary sewage treatment plants in the Greater Vancourver Sewerage and Drainage District, plus primary plants in San Francisco and Seattle. Summation of toxic units attributed to anionic surfactants, unionized ammonia, cyanide, nitrite, and metals measured failed to account for all the acute toxicity measured. (Author's abstract: modified)

Activity: sewage disposal.

Impact: change in levels of heavy metals; change in levels of chlorinated compounds; change in levels of other toxic compounds - other.

Shaw, D.G. 1984. Environmental management of Port Valdez, Alaska: scientific basis and practical results. Summary report of a workshop held in Anchorage, AK., Sept. 1983. Univ. Alaska, IMS, Fairbanks. 113 pp. (ADF&G, Habitat Library, #B3566.)

A variety of benthic species, including barnacles, mussels, and clams in the intertidal and subtidal areas of the Port of Valdez have been studied to determine the effects of tanker ballast discharge. This workshop summarized the results of field and laboratory studies, which have been conducted since the beginning of tanker operations in 1977.

Six kinds of environmental alterations have been documented near the oil terminal since operations began and may be associated with petroleum discharge: hydrocarbon concentrations have increased in sediments and in tissues of mussels, benthic infauna community structure has changed, mussel recruitment has been abnormal, numbers of hydrocarbon degrading bacteria have increased, several changes have occurred in the barnacle _Balanus balanoides_, and population density of the clam _Macoma balthica_ has declined. The workshop participants agreed that the available data do not indicate that the current levels and duration of petroleum discharge into Port Valdez have led to widespread environmental alterations.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Shaw, P.A., and J.A. Maga. 1943. The effect of mining silt on yield of fry from salmon spawning beds. Calif. Fish Game 29(1):29-41. (ADF&G, Habitat Library, #R2721.)

Data presented in this paper show that mine silt deposited on gravel spawning beds during either the early or later stages of incubation results in negligible yields of fry. This damage would occur when mining silt enters a stream at times other than storm periods, when the water velocity is insufficient to carry the sediment in suspension.

Activity: dredging; grading/plowing.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Shaw, D.G., L.E. Clement, D.J. McIntosh, and M.S. Stekoll. 1981. Some effects of petroleum on nearshore Alaskan marine organisms. Corvallis ERL, Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, OR. EPA 600/3-81-018. 83 pp. (ADF&G, Habitat Library, #B6151.)

The objective of this project was to study the effects of chronic, low-level oil pollution from Prudhoe Bay crude oil on nearshore Alaskan marine organisms. The organism studied was the intertidal bivalve mollusk, *Macoma balthica*. An oil-in-seawater concentration of 3.0 mg/l caused severe dysfunction in clams including decreased burial rate, increased respiration rate, and inhibition of growth, leading to very high mortalities. The lowest concentration of oil tested, 0.03 mg/l, inhibited growth and caused abnormalities in gonad morphology. One group of adverse oil effects that was related to sluggishness and disorientation appeared after 7 d oiling; other effects related to negative energy balance were not observed until 60 d. The authors concluded that chronic exposure to oil-in-seawater concentrations as low as 0.03 mg/l will in time lead to population decreases.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Sheeter, G.R., and E.W. Claire. 1981. Use of juniper trees to stabilize eroding streambanks on the South Fork John Day River. USDI:BLM. T/N: OR-1; Filing Code G763, Portland, OR. (ADF&G, Habitat Library, #R5123.)

Cut juniper trees anchored along eroded banks proved beneficial in stabilizing them, often during the first year. This study indicates that juniper revetment is a successful substitute for costly rock structures on straight or slightly curved banks. Failure occurred on only 4% of the banks treated between 1974 and 1979. Failures were associated with improper anchoring and placement of trees on outside curves. (Authors' summary)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of substrate materials; alteration of natural cover - riparian vegetation.

Sheridan, W.L., and W.J. McNeil. 1968. Some effects of logging on two salmon streams in Alaska. J. For.: Feb. 1968:128-133. (ADF&G, Habitat Library, #R2669.)

Sedimentation of spawning beds and density of pink salmon were observed before and after logging in two streams in southeastern Alaska. The study lasted 7 yr, from 1958 to 1964. Although the amount of fine particles in spawning beds increased temporarily, the amount in 1964 (5 yr after logging) was not significantly greater than in 1959. Densities of salmon spawners and fry increased in the sampling areas, probably due to the abolition of salmon traps in 1959. (Author's abstract: modified)

Activity: clearing and tree harvest.

Impact: change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - aquatic vegetation.

Sherk, J.A., J.M. O'Connor, and D.A. Neumann. 1976. Effects of suspended solids on selected estaurine plankton. U.S. Army, Corps of Engineers, Coastal Engineering Research Center. Misc. Rept. No. 76-1. 50 pp. (ADF&G, Habitat Library, #B2188.)

This report presents the effects of suspended particles on carbon assimilation of four common phytoplankton species and on the feeding rates of two common copepods. The experimental concentrations of particles used were typical of those found in estuarine systems during flooding, storm agitation, dredging, and dredged-material disposal. Sediment suspensions reduced the feeding rates of the two copepods tested. The suspensions also reduced the carbon assimilation of the phytoplankton by 50 to 90%, probably by light loss.

These experiments were designed to measure the feeding rate of the copepods, rather than stress. The authors caution that a dense sediment suspension could result in reduced consumption of food particles by the copepods, which over time could cause population depletion and a break in the food chain.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials.

Shields, F.D. 1982. Environmental features for flood-control channels. Prepared for Office, Chief of Engineers, U.S. Army, Tech. Rept. No. E-82-7. Washington, D.C., 107 pp. + appendix. (ADF&G, Habitat Library, #B1891.)

This report presents and documents preliminary findings of an information review performed to develop environmental guidance for flood-control projects that involve modification of natural stream channels by clearing and snagging, alignment, enlargement, and lining. The response of the fluvial system to modification sometimes results in unintentional or unforeseen environmental impacts.

In general, channel modification results in a shorter, smoother, more uniform channel with larger cross-sectional area and less natural vegetation. Overbank flooding is eliminated or reduced, and depths and velovities are changed at all flows. Because extreme channel instability has adverse effects on ecological and aesthetic resources, channel straightening should be minimized. The channel cross section should be designed for low as well as high flows; the existing velocity-versus-discharge relationship should be preserved as much as possible at low and intermediate flows to maintain the sediment transport characteristics of the existing channel. Environmental features have been found to have limited effectiveness unless the modified channel is reasonably stable, the project area is protected against further modification, and construction and maintenance work is closely supervised and inspected.

The adverse environmental impacts of channel enlargement can be reduced by following the existing channel alignment and excavating from one side only. Floodways may be used to preserve portions of the existing channel and its associated aquatic habitat. Low-flow channels may be constructed inside a larger channel, or the existing channel may be preserved as a low-flow channel. Pools and riffles may be constructed. Water-control structures may be placed in the channel to maintain water levels for aquatic habitat and aesthetics and to prevent invasion and blockage. Meander loops may be maintained as small ponds or wetlands.

Many of the adverse impacts of channel work can be avoided by preservation of existing valuable vegetation and by prompt revegetation with appropriate species. Aquatic habitat diversity may be restored to a modified channel by placing simple habitat structures in the channel to create vertical relief, nonuniform flow patterns, and stable substrate; these devices should be used with care because they increase hydraulic roughness and tend to offset flood control measures. Biological recovery of some modified streams may be improved by armoring the new channel with biologically desirable coarse bed material. Adverse impacts of channel lining or paving may be addressed by incorporating natural materials, such as boulders, in the lining, by ponding water in the lined channel, and by constructing low-flow channels, fishways, pools, and spawning channels. (Author's abstract)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; change in levels of nutrients.

Shields, F.D., and M.R. Palermo. 1982. Assessment of environmental considerations in the design and construction of waterway projects. U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, Tech. Rept. No. E-82-8, Vicksburg, MS. 210 pp. + appendix. (ADF&G, Habitat Library, #B1884.)

This report identifies factors and constraints in design and construction of waterway projects affecting environmental quality. Waterway projects covered in this report include channel modifications for both flood control and navigation, dikes, stream bank protection, and levees. Locks and dams and flood-control dams are not addressed. Flood-control channel modifications include clearing and snagging; channel enlargement, alignment, and relocation; and channel stabilization using grade-control structures or streambank protection.

The information presented in this report was collected from literature reviews, personal interviews, and visits to Corps of Engineers (CE) field offices and waterway projects. Design and construction practices for each major project type are summarized, and environmental impacts are identified. Recent developments in design and construction practices to reduce adverse impacts and ongoing relevant research are reviewed.

Adverse environmental impacts of flood-control channel modification include loss of valuable habitats and habitat diversity, channel instability, reduction of aesthetic value, water quality degradation, and undesirable hydrologic changes. The severity and nature of environmental impact varies considerably from project to project. Methods to reduce adverse impacts included stream restoration, artificial in-stream structures, modified channel cross sections, and management of cutoff meanders.

Immediate and eventual losses of backwater habitat are a major impact of navigation channel modification projects.

The major environmental impact associated with dikes is the reduction in water surface area and loss of habitat diversity due to sediment accretion in the dike field. In some situations, the rate of sediment accretion may be reduced by constructing notches or gaps in the dikes.

Major adverse effects of stream bank protection include loss of riparian vegetation and reduction in the rate of channel migration. Innovative stream bank protection designs that reduce adverse impacts feature vegetation and combinations of structure and vegetation.

The major environmental impact of levees is related to their purpose: the creation of drier conditions on the land side of the levee is frequently associated with land use changes. Recent efforts to incorporate environmental considerations in levee projects include management of vegetation on and around levees for wildlfie and aesthetics and recreational features.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Shumway, D.L., C.E. Warren, and P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Tran. Am. Fish. Soc. 93(4):342-350. (ADF&G, Habitat Library, #R3641.)

Embryos of coho salmon and steelhead trout were reared from fertilization of the eggs to hatching, at about 10°C, at different concentrations of dissolved oxygen ranging from about 2.5 to 11.5 mg/l and at different water velocities ranging from about 3 to 750 cm/h. Some of the embryos rested on porous plates, while others were buried in glass beads so as to simulate natural conditions more closely. Fry from embryos reared at low and intermediate oxygen concentrations hatched later and were smaller in size at hatching than fry from embryos reared at concentrations near the air-saturation level. At all oxygen concentrations tested, reduced water velocities resulted in reduced size of hatching fry. This effect of velocity was nearly as pronounced at high oxygen concentrations as at low concentrations. The effect of the difference of water velocities tested was less than the effect of the difference of oxygen concentrations tested. When some embryos were buried in glass beads while others were not and the discharge rates of water through cylinders containing the embryos were the same, the fry that hatched in the cylinders containing beads were larger in size than those in cylinders without beads. This effect is ascribed to the increase of water velocities around the embryos buried in beads. It was usually most pronounced when a mixture of large and small beads was used. (Author's abstract: modified)

Activity: clearing and tree harvest; dredging; grading/plowing; sewage disposal.

Impact: change in level of dissolved oxygen, nitrogen.

Sibert, J.R., and V.J. Harpham. 1979. Effects of intertidal log storage on the merofauna and interstitial environment of the Nanaimo River delta. Fisheries and Marine Services Tech. Rept. 883. Dept. Fisheries and Oceans, Nanaimo, B.C. 27 pp. (ADF&G, Habitat Library, #B4363.)

Merofauna and interstitial habitat under intertidal log storage rafts were studied in the spring of 1978 on the Nanaimo River delta. Total abundance of major merofauna taxa at several field sites could not be related to the presence of log booms. Species composition of harpacticoid copepod populations showed that interstitial species were small in size and that epibenthic species usually predominated under booms. There are three distinct habitat types associated with booming: alley, under boom, and near dolphin. These three habitat types should be ampled in further studies.

Greatest indications of habitat disruption were physical. Sediments were compressed, and the anoxic zone was closer to the sediment surface. Other features suggested that the ability of currents to transport suspended material was decreased by the presence of booms. These conclusions are compared to other studies of intertidal log storage in Alaska and Washington.

Activity: log storage/transport.

Impact: physical disturbance of substrate materials; addition of physical barriers - partial obstructions; change in level of dissolved oxygen, nitrogen.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Trans. Am. Fish. Soc. 113:142-150. (ADF&G, Habitat Library, #R3855.)

Laboratory tests were conducted in three facilities over a 2-yr period to determine the effect of chronic turbidity on feeding, growth, and social interactions of steelhead trout (Salmo gairdneri Richardson) and coho salmon (Oncorhynchus kisutch Walbaum). Differences in feeding capability and growth between fish reared in clear water (zero turbidity) were indirectly assessed by measuring differences in the size-related variables of condition factor, ending weight and length, and mean daily weight and length increases.

Fish fry 30-65 mm in length were subjected to varying degrees of turbidity in artificial streams. Fish tended to emigrate, especially smaller ones (less than 40 mm), from turbid to less turbid stream sections. Growth rates of fish subject to continuous turbidity of 25 NTU or more were lower than those of fish in clearwater stream sections. Gill damage was not observed for any fish examined until after 3 to 5 d of testing. Exposure to chronic turbidity of varying levels reduces growth in coho salmon and steelhead trout fry. Consistently, fish reared in clear water were larger than fish in turbid water.

Exposure to chronic turbidity tended to reduce population densities in artificial stream environments. Rearing in turbid water altered behavior patterns of both species and reduced competitive capability as evidenced by the increased percentages of turbid water emigrants from competition tests. (Authors abstract: modified)

Activity: channelizing waterways; clearing and tree harvest; dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments.

Sigman, M. 1985. Review of potential impacts of installation of marine pilings. treated with creosote on marine organisms. Unpubl. rept., ADF&G, Div. Habitat. 13 pp. (ADF&G, Habitat Library, #R3423.)

This paper reviews the potential toxic effects of chemical leachates from creosote-treated wooden pilings on marine organisms in the context of Alaska State Water Quality Standards. The paper summarizes the literature concerning toxicity testing of creosote and its phenol and cresols constituents for salmonids and other marine and intertidal species. Creosote, phenols, and cresols result in physiological damage and rapid mortality (based on LC_{50} mortality rates) for a variety of marine and freshwater organisms at low-to-moderate concentrations ranging from .001 to 11.6 ppm.

Information concerning actual leaching rates of toxic compounds is scanty. Factors that may potentially mitigate impacts to marine organisms are the possibility that leaching rates are insignificant, the effects of tidal mixing, rapid biodegradation of compounds under some conditions, and the physiological capabilities of organisms to rid themselves of compounds when they move to clean waters.

A monitoring program to determine concentrations of toxic compounds around newly installed and older wooden pilings is recommended to measure toxic compound concentrations which may exceed Alaska State Water Quality Standards, as a basis for determing whether timing restrictions during installation of pilings are adviseable or whether alternatives to use of creosote-treated pilings should be considered during project design to avoid impacts. (Author's abstract)

Activity: filling (aquatic and wetland habitats).

Impact: change in levels of other toxic compounds - other; change in levels of hydrocarbons.

Silsbee, D.G., and G.L. Larson. 1983. A comparison of streams in logged and unlogged areas of Great Smoky Mountains National Park. Hydrobiologia 102(2):99-111. (ADF&G, Habitat Library, #R3828.)

Water quality, benthic macroinvertebrate communities, and physical stream channel characteristics of streams in areas of virgin forest in the Great Smoky Mountains National Park (Tennessee and North Carolina) were compared with those of streams draining areas which had been logged before the establishment of the park in the 1930's. Stream channel characteristics and invertebrate communities were investigated on four formerly logged and four unlogged streams. Water quality sampling, together with more detailed invertebrate sampling, was conducted on two of these eight streams.

Water from the unlogged stream was generally higher in conductivity, nitrate, sulfate, phosphate, calcium, magnesium, sodium, and dissolved organic carbon than water from the logged stream. Water from the logged stream was generally higher in temperature, pH, alkalinity, turbidity, potassium, silica, total and volatile suspended solids, and fecal coliform, faecal streptococcus, and total coliform bacteria.

Substrate of the logged and unlogged streams was similar in composition, but the logged streams had more of a 3-10 cm size class of rocks than the unlogged streams. The unlogged streams had over 4 times the volume of woody debris and 10 times the volume of debris dams of the logged streams. Debris in the logged streams tended to be smaller in size and fresher in condition than those in the unlogged streams.

Macroinvertebrate samples from the same streams showed a pattern of greater numbers of organisms in the streams draining logged areas. The more detailed sampling showed a similar difference in the total number of organisms, as well as greater biomass and more taxa in the logged stream. Differences in the relative importance of five functional groups were also observed. Seasonal peaks in biomass of the five functional groups corresponded approximately to peaks in the availability of the primary food sources of the groups. (Author's summary)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in water temperature; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation; change in levels of pH, alkalinity, or hardness; change in levels of nutrients.

Simenstad, C.A., W.J. Kinney, S.S. Parker, E.O. Salo, J.R. Cordell, and H. Buechner. 1980. Prey community structure and trophic ecology of outmigrating juvenile chum and pink salmon in Hood Canal, Washington: a synthesis of three years' studies, 1977-1979. Univ. Wash., Fish. Res. Instit., FRI-UW-8206, Seattle, WA. 113 pp. (ADF&G, Habitat Library, #B6248.)

Results from detailed studies of the prey organisms and prey community structure of juvenile chum (Oncorhynchus keta) and pink salmon (O. gorbuscha) in Hood Canal during the 1977-1979 out-migrations suggested that the migration rate of and habitat selection by the juvenile salmon related directly to availability of preferred prey organisms. Both epibenthic (harpacticoid copepods, gammarid amphipods) and neritic (calanoid copepods, hyperiid amphipods, larvaceans) zooplankton were important prey taxa, depending upon the size of the fish and the stage in the out-migration. Juvenile chum salmon entering Hood Canal early in the out-migration (February-March), especially naturally spawned chums less than 40 mm FL, encountered relatively meager prey resources in shallow sublittoral and neritic habitats. Rapid migration rates during this period suggested a behavioral response to low prey availability might have included immediate migration into habitats or regions with higher densities of preferred prey. In spring, as prey resources increased, migration rates decreased as the juvenile salmon spent more time foraging in nearshore habitats. During spring, small fish (less than approximately 50 mm) initially fed upon epibenthic zooplankton; upon growing to 45-55 mm FL (or being released at or larger than that size from hatcheries) they moved into neritic habitats and fed upon pelagic and nektonic zooplankton. Both depletion of epibenthic zooplankton and growth of the fish to the point that they could feed upon larger neritic prey and avoid predators may have been responsible for this habitat transition.

Selectivity for large prey was quite apparent in both epibenthic and neritic feeding modes and could be attributed to a number of mechanisms, including 1) visual perception and active selection, 2) differential prey escape abilities, 3) functional morphology of the juvenile salmon, and 4) optimization of bioenergetic cost of foraging with nutritional value or prey. Comparison of biweekly estimates of surplus carrying capacity of Hood Canal for juvenile chum salmon and the abundance of almost 16 x 10^6 juvenile chums entering the canal in 1978 indicate that the existing densities of fish depleted the resources of utilizable epibenthic prey until early May, when the size of fish and increases in neritic zooplankton enabled the out-migrating chums to move into neritic habitats to feed. A number of recommendations were proferred relative to further research and development of hatchery release strategies based upon the estimated surplus carrying capacity of such estuarine and nearshore rearing habitats. (Authors' Abstract)

Activity: filling (aquatic and wetland habitats).

Impact: addition of physical barriers - partial obstructions.

Simmons, R.C. 1984. Effects of placer mining sedimentation on arctic grayling of interior Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 75 pp. (ADF&G, Habitat Library, #B0938.)

The effects of suspended sediment (in quantities greater than 500 mg/l) produced by placer mining activity, on arctic grayling (<u>Thymallus arcticus</u>) was studied during the summers of 1982 and 1983 in the headwaters of Birch Creek and the Chatanika River drainages, northeast of Fairbanks, Alaska. Data were collected on each drainage near confluences of streams where one was undisturbed and the other undergoing mining activity. Many age 0 and adult grayling were found in unmined streams; however, no grayling were found in mined streams, except during periods of migration. Grayling consistently chose clearwater areas for summer residence. Caged fish studies demonstrated that grayling suffered various direct, chronic effects from suspended sediment, including gill damage, dietary deficiencies, and slowed maturation. Indirect impacts of suspended sediment were loss of summer habitat for feeding and reproduction. (Author's abstract: modified)

Activity: dredging; processing minerals.

Impact: change in turbidity or suspended sediments.

Simpson, P.W., J.R. Newman, M.A. Keirn, R.M. Matter, and P.A. Guythrie. 1982. Manual of stream channelization impacts on fish and wildlife. USFWS - Office of Biological Services, Washington, DC. Publ. No. FWS/OBS-82-24. 155 pp. (ADF&G, Habitat Library, #B0737.)

This manual contains a synthesis of literature dealing with the effects of stream channelization on fish and wildlife resources. Information is summarized to provide an overview and general understanding of key studies in channelizing. Channelization includes clearing and snagging, riprapping, widening, deepening, realigning, and lining a stream.

Physical impacts on streams include a change in form and substrate. Depth and width, surface area, length, configuration and bedform, substrate, cover, gradient, flow, and velocity are other physical features that can be impacted by channelization. The water column is characterized by physical attributes that can be affected, such as solids and sediments, light, and temperature. Chemical characteristics that have been impacted include dissolved oxygen and other gases, dissolved solids, oxygen demand, nutrients, and toxic substances.

Stream systems are highly variable, and channelization activities can affect a combination of physical and chemical characteristics. The net result could be a stream environment that directly or indirectly affects the biological components. Direct effects include mortality or injury to organisms and loss of habitat. Indirect effects result from habitat alterations that create less favorable conditions for aquatic organisms. Shifts in species composition, dominance, diversity, and biomass can favor organisms more tolerant to the resulting changes.

For aquatic organisms, major impacts of channelization occur from loss of substrate; removal of snags, detritus, and debris; loss of instream vegetation; loss of streamside vegetation; disruption of the run-riffle-pool sequence; loss of stream length; increased gradient and velocity; dewatering of adjacent areas; alteration of the physiochemical regime; and reduction of allochthonous input

Direct impacts of terrestrial and riparian habitats are clearing of vegetation, dredging, and soil deposition. Indirect effects on vegetation occur from the draining and dewatering effect that the channel creates. Associated with this drying, land use changes occur that may further alter vegetation communities. Loss of woody species, decreased diversity, successional changes, loss of productivity, and physiological changes can impact vegetation. Impacts on the aquatic and vegetation systems ultimately affect wildlife groups.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

Singleton, G.A., O.A. Steen, K. Weagle, and D. Weir. 1981. Fish and wildlife habitat recovery in placer mined areas of the Yukon. Final rept. to the Department of Indian Affairs and Northern Development. 130 pp. (ADF&G, Habitat Library, #B2257.)

Fish habitats in several placer-mined drainages were assessed for physical characteristics, water quality, and benthic community parameters. Physical parameters such as velocity, substrate, and channel characteristics were found to be the greatest limitation to grayling habitat recovery. Placer-mining operations were classified as wide valleys, narrow valleys, or other operations. Wide valleys allowed tailing disposal within the valley without encroachment on the valley walls; tailing disposal in narrow valleys could be accommodated only on valley walls.

From 29 to 72 yr were found to be required to restore the physical habitat of placer-mined wide valleys to control levels, and, in narrow valleys, no trends of physical habitat recovery were observed.

Water quality in wide valleys was found to return to control levels in approximately 20 yr, whereas no predictable trend to recovery was observed in water quality data from narrow valleys. Too few other types of operations, high bench and hydraulic, were examined to make conclusions on recovery.

Benthic community densities in wide and narrow valley streams recovered in approximately 5 yr following mining. However, the narrow valley streams did not return to control diversities and became dominated with sediment-tolerant organisms.

The authors conclude that a lack of channel stability and low flow are the most limiting factors to fish habitat recovery.

Activity: processing minerals.

Impact: change in depth or velocity of water; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - overhanging bank or shoreline.

Smith, D.G. 1976. Effect of vegetation on lateral migration of anastomosed channels of a glacier meltwater river. Geol. Soc. Am. Bull. 87:857-860. (ADF&G, Habitat Library, #R5109.)

A series of experiments were performed on bank materials of anastomosed channels in floodplain silt deposits in the Alexandra Valley in Banff Park, Alberta, to determine the effect of vegetation roots on bank erodibility and lateral migration of channels. Underground roots from the dense growth of meadow grass and scrub willow provide the reinforcement of bank sediment and a riprap-like protection of channel banks from river erosion. Experimental results suggested that in cool environments with aggrading river conditions where overbank deposition of silt, clay, and fine sand dominate the valley fill, vegetation roots are able to rapidly accumulate and decay very slowly, thus affording protection to banks from erosion in deeper parts of the channels. Experimental results, using a specially designed erosion box, indicated that bank sediment with 16 to 18% of roots, by volume, had 20,000 times more resistance to erosion than comparable bank sediment without vegeetation. (Annotation from Stern and Stern 1980b)

Activity: channelizing waterways; clearing and tree harvest; grading/plowing.

Impact: alteration of natural cover - riparian vegetation.

Smith, D.W. 1978. Tolerance of juvenile chum salmon (Oncorhynchus keta) to suspended sediments. M.S. Thesis, Univ. Washington, Seattle. 124 pp. (ADF&G, Habitat Library, #B5946.)

Static bioassays were used to determine the tolerance of seawater-adapted chum salmon to the direct effects of suspended sediments. Sublethal bioassays were also conducted, using blood plasma glucose concentration as an indicator of stress. The study was conducted on a floating laboratory situated close to dredging activity at Bangor, Washington (Hood Canal).

Suspended sediment values that induced 50% population mortality over a 96-h period ranged between 15.8 and 54.9 g/l and are considered the best estimates of median lethal thresholds.

Silt accumulation in opercular cavities and gill coating were observed, but no cellular damage was evident. Low tolerance to sediments was associated with high concentrations of dissolved heavy metals. An effect of water temperature on tolerance was not observed.

Several fish exposed to suspended overburden (large particles) for 10-20 d exhibited tail rot.

Fish placed in high concentrations of suspended sediments demonstrated symptoms of depressed available oxygen (hypoxia).

Activity: clearing and tree harvest; dredging; grading/plowing; processing minerals.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Smith, E.J., and J.L. Sykora. 1976. Early developmental effects of lime-neutralized iron hydroxide suspensions on brook trout and coho salmon. Trans. Am. Fish. Soc. 2:308-312. (ADF&G, Habitat Library, #R3018.)

Acid drainage from coal-mining operations often contains high levels of dissolved ferrous iron (Fe^{2+}), which converts to insoluble ferric (Fe^{3+}) species, including particulate ferric hydroxide ($Fe[OH]_3$), as pH is elevated and oxygenation takes place. The neutralization of acidic coal mine effluents by the addition of lime ($Ca[OH]_2$) slurry, a commonly practiced method of acid mine drainage abatement, will also result in the production of ferric hydroxide, which is normally removed by sedimentation. This study dealt with brook trout and coho salmon egg and alevin responses to experimental exposures to lime-neutralized iron hydroxide suspensions.

Effects were interpreted from data on hatchability, survival, and growth in five test concentrations and control. Growth of 90-d-old coho salmon alevins was reduced in water containing 1.27 mg Fe/l of lime-neutralized suspended iron, whereas hatchability was unaffected in the highest concentration tested, 10.5 mg Fe/l. However, 10.5 mg Fe/l water had no measurable effect on hatchability, survival, and growth of brook trout alevins. The safe upper limit of lime-neutralized suspended iron for hatchability, survival, and growth of coho salmon alevins may lie between 0.97 and 1.27 mg Fe/l. (Author's abstract: partial)

Activity: processing minerals.

Impact: change in turbidity or suspended sediments; change in levels of other toxic compounds - other.

Soroka, I.K., and G. Mackenzie-Grieve. 1983. A biological and water quality assessment at a placer mine on Little Gold Creek, Yukon Territory. Environment Canada, Environmental Protection Service, Pacific Region, Regional Program Rept. No. 83-06. 105 pp. (ADF&G, Habitat Library, #B2532.)

An assessment of water quality and biological conditions at a placer gold mine site on Little Gold Creek was carried out during the period June to September 1982. The water quality, sediment, and bottom fauna characteristics were documented at five sample stations.

Water quality parameters were seen to be dramatically influenced by activity at the placer mine. During periods of sluicing activity, elevated values of suspended sediments, settleable solids, filterable residue, turbidity, and the extractable heavy metals were observed at downstream locations. Dissolved oxygen levels and pH values were lower at downstream locations during sluicing.

Sediment composition of the stream bottom increased in the percentage of fine sands and silts at downstream locations during sluicing. These fine sediments were seen to have lower extractable heavy metal values than the more coarse sediments of the control station. This was attributed to the larger and heavier metal-bearing particles being deposited in the settling-pond system. Stream bottom composition was observed to return to a composition more typical of the control station after extended periods of no sluicing activity.
The abundance and diversity of bottom fauna were determined. Diversity indices indicate that stations subjected to the influence of the placer mine activity had lower diversity and fewer organisms than the control. The composition of benthic invertebrates changed from a community dominated by members of the Ephemeroptera and Plecoptera at the control station to a community dominated by members of the Diptera at stations subject to the placer mining. (Author's abstract)

Activity: processing minerals.

Impact: addition of substrate materials; physical disturbance of substrate materials; change in levels of heavy metals.

Sprague, J.B., J.H. Vandermeulen, and P.G. Wells. 1982. Oil and dispersants in Canadian seas - research appraisal and recommendations. Environment Canada. Environmental Protection Service, Econ. and Techn. Rev. Rept. EPS 3-EC-82-2. Ottawa, Ontario, Can. KIAIC8. 185 PP. (ADF&G, Habitat Library, #B5374.)

This report evaluates knowledge of the fate and effects of oil spilled at sea and the implications of using dispersants, with special reference to Canadian marine environments. Almost 600 references from the scientific literature are utilized. Twelve chapters by individual scientists give perspectives on the Canadian oil industry; fate and behaviour of oil in the sea; microorganisms and degradation of oil; analytical chemistry; and effects of oil, dispersants, and chemically-dispersed oil on phytoplankton, macrophytes, zooplankton, fish, benthic and intertidal organisms, birds, marine mammals, and communities and ecosystems. Recommendations are given for further research that is required and strategies for minimizing effects of spills, again with emphasis on Canadian waters. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Starr, S.J., M.N. Kuwada, and L.L. Trasky. 1981. Recommendations for minimizing the impacts of hydrocarbon development on the fish, wildlife, and aquatic plant resources of the northern Bering Sea and Norton Sound. ADF&G, Div. Habitat, Anchorage. 525 pp. + 17 maps. (ADF&G, Habitat Library, #B1511.)

This document describes oil and gas activities leading to environmental disturbances and discusses the sources of impacts to fish and wildlife resources. Activities associated with oil and gas development include 1) geophysical surveying, 2) exploratory drilling, 3) production drilling and platform installation, and 4) laying submarine pipelines when development is offshore. Onshore development mainly involves the construction of 1) service bases, 2) platform fabrication yards, 3) treatment facilities, 4) oil or marine terminals, 5) oil refineries, 6) petrochemical plants, and 7) liquified natural gas plants. Sources of impacts to fish and wildlife resources resulting from these activities include oil pollution, drilling muds and cuttings, noise and disturbance, dredging and filling, gravel mining, gravel islands, shoreline alteration, formation waters, cooling waters and water withdrawal, secondary development, harvest interference, and air pollution.

The biological effects of impact-causing activities on fish, wildlife, aquatic plants and their habitats are presented in annotated bibliographies that cover drilling and cutting; oil pollution, dredging and filling, gravel islands; shoreline alteration; formation waters and formation water components; and cooling waters and water withdrawals. Included is a glossary that defines many of the terms used by the oil and gas industry.

Activity: blasting; dredging; drilling; filling (aquatic and wetland habitats); processing oil/gas; transport of oil/gas/ water - water; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions; increase in hydrostatic pressure or noise; impingement or entrainment or entanglement; change in levels of hydrocarbons.

Stednick, J.D., Tripp, L.N., and R.J. McDonald. 1982. Slash burning effects on soil and water chemistry in southeastern Alaska. J. Soil Water Conserv. 37(2):126-128. (ADF&G, Habitat Library, #R3851.)

Stream water samples and soil samples were analyzed to determine the effects of slash burning on soil and water resources in the coastal hemlock-spruce, and sitka spruce forests of southeastern Alaska. A comparison of water samples from above and below the burned area showed that slash burning after timber harvest increased total phosphorus and potassium concentrations in stream flow. Suspended sediment concentrations and optical turbidity exhibited variable relationships. Suspended sediment concentrations were significantly greater below the burned area, but no sample exceeded Alaska's water quality standard of 5.0 NTUs. A comparison of soil samples from an adjacent logged but unburned area with samples from the burned area showed no reduction in the depth of the soil organic horizon as a result of burning. Neither did the nitrogen content in the organic horizon change after burning, but burning after timber harvest significantly reduced the potassium and magnesium contents of the horizon. What changes in soil and water resources did occur as a result of timber harvest and slash burning will not reduce site productivity or result in long-term degradation of these resources. (Author's abstract)

Activity: burning.

Impact: change in turbidity or suspended sediments; change in levels of nutrients.

Stern, D.H., and M.S. Stern. 1980a. Effects of bank stabilization on the physical and chemical characteristics of streams and small rivers: a synthesis. USFWS - Office of Biological Services, Washington, D.C. Publ. No. FWS/OBS-80/11. 43 pp. (ADF&G, Habitat Library, #B2049.)

This report presents information on the impacts of bank stabilization on streams and small rivers (defined as those that can be waded or used only by small pleasure boats). Strategies for dealing with some bank stabilization problems are also discussed briefly.

Bank stabilization is generally carried out as one of four widely used techniques for channel modification or "improvement," the other ones being 1) widening, deepening, and straightening; 2) clearing and snagging; and 3) diking. Bank stabilization efforts are directed at reducing or preventing bank erosion problems. A number of physical-chemical factors can be affected by bank stabilization measures or other water development activities. Ten such factors were selected as being sensitive to such activities and are examined individually in the text. The factors include 1) depth and stage; 2) water surface area of channel and floodplain; 3) channel configuration; 4) water current velocity; 5) water temperature; 6) suspended solids; 7) bed materials, including bedload; 8) dissolved substances; 9) light transmissivity; and 10) flow variability.

In conclusion, the authors cite studies that state, "Flowing waters with stabilized banks are dynamic systems that are frequently unstable morphologically and biologically, and are unpleasing aesthetically. Stabilized channels respond to any alterations in bank or channel geometry and flow regime, such as depth, and state, or sediment transport. When one variable changes, one or more additional variables, in turn, respond to that change and are themselves altered."

When a streambank is modified locally, banks above and below the modified reach exhibit responses observable over long distances. Energy that is no longer dissipated in eroding a newly riprapped bank will be transferred to an unprotected reach elsewhere. Piecemeal application of riprap may provide a short-run solution to an obvious problem but may intensify long-run problems.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

Stern, D.S., and M.S. Stern. 1980b. Effects of bank stabilization on the physical and chemical characteristics of streams and small rivers: an annotated bibliography. USFWS - Office of Biological Services, Washington, D.C. Publ. No. FWS/OBS-80/12. 78 pp. (ADF&G, Habitat Library, #B6162.)

This annotated bibliography provides a reference source of information on the impacts of bank stabilization on the physical and chemical characteristics of small streams and rivers (defined as those that can be waded or used only by small pleasure boats). The bibliography has 213 references and is indexed by 26 key subject headings. Papers range from technical documents to general discussions addressing the physical and chemical changes that result from various types of bank stabilization activities. Many of the annotations provide a thorough summary of pertinent information in the respective references.

The indexed subjects include the following:

- Bed material (including sedimentation)
- Bibliography
- Channel configuration
- Channelization impacts
- Coastal
- Construction
- Depth and stage (including flooding)
- Design and planning (guidelines)
- Dissolved substances
- Ecology
- Erosion, bank
- Erosion, bed
- Erosion, other
- Fauna, benthos
- Fauna, fish
- Fauna, other
- Flow variability
- Surface area
- Surveys
- Suspended solids (including turbidity and light transmissivity)
- Techniques: bank/bed protection
- Techniques: soil stabilization
- Temperature
- Vegetation, establishment/planning of
- Vegetation, natural
- Velocity

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

Stern, E.M., and W.B. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments: literature review. U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss. Tech. Rept. D-78-21. 117 pp. (ADF&G, Habitat Library, #B1889.)

Stern and Stickle present evidence to show that turbidity and suspended material can play both a beneficial and detrimental role in aquatic environments. Suspended material can remove contaminants from the water column and stimulate photosynthesis by introducing inorganic nutrients. However, the nutrients can stimulate excessive growth, and turbidity can interfere with photosynthesis by reducing light penetration.

Turbidity and suspended material have adverse effects on the filter-feeding invertebrates. Most studies indicate that, with exposure to temporary increases in turbidity and suspended material similar to that encountered where dredging or disposal has occurred, no permanent effects were exhibited. As a group, fish are more sensitive to suspended solids than are most invertebrates.

Direct effects of turbidity and suspended solids to fish include lethal agents and factors that influence reproduction, growth, and development or that produce abrasive wear on tissues. Several laboratory studies indicated that fish eggs incubated in suspensions of varying concentrations showed a delay of several hours in hatching. Within a given species, the juveniles generally were more sensitive to concentrations of suspended solids than adults.

The results of these studies have indicated that fish as well as invertebrates are affected by a complex interaction between suspended solids, temperature, and dissolved oxygen. A correlation exists between normal habitat and sensitivity to suspended solids. The most tolerant species are the bottom dwellers, and the filter feeders are the most sensitive. High suspended solids concentrations would be less harmful in winter than in summer.

Activity: dredging; grading/plowing; solid waste disposal.

Impact: change in turbidity or suspended sediments; change in levels of heavy metals; change in levels of biocides; change in levels of nutrients.

Stewart, R.K., and D.R. Tangerone. 1977. Water quality investigation related to seafood processing waste water discharges at Dutch Harbor, Alaska. Working Paper No. EPA-910-8-77-100. Environmental Protection Agency, Surveillance and Analysis Division. Seattle, WA. 77 pp. (ADF&G, Habitat Library, #B2184.)

At the time of this study, approximately 48 million pounds (22 million kg) of seafood wastes were being ground and discharged into waters of the Dutch Harbor area every year. In the study, water quality measurements were taken in areas near waste outfalls and compared with measurements taken in non-affected areas. Low dissolved oxygen concentrations (at some stations below 6 mg/l) near the bottom, increased ammonia and total phosphorus concentrations within bays, and decomposing sludge deposits of seafood wastes were encountered in surveys conducted in both 1975 and 1976. Water current movement in Dutch Harbor was found from diving and current drouge observations to be negligible. Thus, waste solids discharged into Dutch Harbor do not readily disperse. Decomposition of the accumulated wastes apparently results in the observed poor water quality.

Activity: solid waste disposal.

Impact: addition of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of nutrients.

Stickle, W.B., T.D. Sabourin, S.D. Rice. 1982. Sensitivity and osmoregulation of coho salmon, _Oncorhynchus kisutch_ exposed to toluene and naphthalene at different salinities. Pages 331-348 _in_ W.B. Vernberg, A. Calabrese, F.P. Thruberg, and J.F. Vernberg, eds., Physiological mechanisms of marine pollutant toxicity. New York: Academic Press. (ADF&G, Habitat Library, #R4272.)

Coho salmon (_Oncorhynchus kisutch_) smolts were more sensitive to toluene and naphthalene in seawater than in freshwater. Tolerance dropped linearly from 0 through 10, 20, and 30 ppt salinity. Smolt tolerances at 30 ppt salinity were 54 and 63% of the 48-h TLm in fresh water for toluene and naphthalene, respectively. Smolt tolerances to toluene and naphthalene were the same after 12, 22, and 42 d of acclimation to sea water as they were after only 1 d of acclimation. The increase in sensitivity was not transient nor did it appear related to acclimation-stress because the smolts gained 30% in weight 42 d.

Toluene and naphthalene affected serum osmolality and ions but only at the lethal concentrations of 100 and 130% of the 48-h TLm. At those exposure concentrations, osmolality, Na^+, and Cl drifted with the diffusion gradient, decreased in fresh water smolts and increased in sea water smolts. At the same concentration, K^+ concentrations in the serum increased, even in fresh water smolts, indicating cellular damage. Exposures of 70% of the 48-h TLm had no effect on serum osmolality or ions. Consequently, we conclude that the increase in sensitivity of smolts in sea water is not related to a failure in ion-regulating ability but rather the loss of ion-regulating ability at lethal exposures is symptomatic of toxic actions elsewhere. The cause of increased sensitivity of smolts in sea water is not transient and remains unknown. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in level of salinity; change in levels of hydrocarbons.

Stickle, W.B., Jr., S.D. Rice, and D.A. Moles. 1984. Bioenergetics and survival of the marine snail, _Thais lima_ during long-term oil exposure. Mar. Biol. (Berl.) 80:281-289. (ADF&G, Habitat Library, #R3701.).

The carnivorous snail _Thais lima_ was fed _Mytilusul_ _edulis_ during a 28-d exposure to the water soluble fraction (WSF) of Cook Inlet crude oil. The LC_{50} of _T. lima_ declined from greater than 3,000 ppb aromatic hydrocarbons on Day 7 to 818 $\pm$ 118 ppb aromatic hydrocarbons on day 28. The LC_{50} of _M. edulis_ declined from 3,000 ppb aromatic hydrocarbons on day 7 to 1,686 $\pm$ 42 ppb on day 28. Predation rate declined linearly with increasing aromatic hydrocarbon concentration up to 302 ppb; little predation occurred at 538 ppb and none at 1,160 or 1,761 ppb. Snail absorption efficiency averaged 93.5% and did not vary as a function of WSF dose. Total energy expenditure (R + U) increased at 44 ppb aromatics and declined at lethal WSF exposures. At sublethal WSF exposures, percentages of total energy expenditure were: respiration (87%), ammonia excretion (9%), and primary amine loss (4%). These percentages did not vary as a function of WSF dose or time. Oxygen:nitrogen ratios were not affected by WSF concentration or time and indicated that _T. lima_ derived most of its energy from protein catabolism. The uptake of aromatic hydrocarbons into the soft tissues of snails and mussels was directly related to the WSF concentration. Naphthalenes accounted for 67 to 78% of the aromatic hydrocarbons in _T. lima_ and 56 to 71% in _M. edulis_. The scope for growth was negative above 150 ppb WSF aromatic hydrocarbons and above 1,204 ppb soft-body aromatic hydrocarbons. These snails were physiologically stressed at an aromatic hydrocarbon concentration which was 19% of the 28-d WSF LC50 (818 $\pm$ 118 ppb) and/or 48% of the 28-d LC_{50} of soft tissue aromatics (2,502 ppb). (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Stober, Q.T., P.A. Dinnel, E.F. Hurlburt, and D.H. DiJulio. 1980. Acute toxicity and behavioral responses of coho salmon (Oncorhynchus kisutch) and shiner perch (Cymatogaster aggregata) to chlorine in heated sea-water. Water Research 14: 347-354. (ADF&G, Habitat Library, #R3896.)

Laboratory tests were used to assess the behavioral responses of fish to plumes of chlorinated water because chlorine is commonly used to control fouling organisms in power plants. Coho salmon consistently showed a significant avoidance response to all test concentrations of chlorine in ambient sea water and to heated sea water. Shiner perch did not show a statistically significant avoidance or preference response to chlorine in ambient sea water. Shiner perch were attracted to heated water and to heated water with low levels of chlorine.

Short exposures of sea water heated to 20°C from 12°C ambient temperature significantly increased the toxicity of chlorinated sea water to both coho salmon and shiner perch. Coho salmon were affected by as little as a 3°C increase in temperature, and similar results for juvenile pink and chinook salmon were noted in another study. The effects of short exposures may be greater than those of longer exposures where the fish can acclimate.

Activity: sewage disposal.

Impact: change in water temperature; change in levels of chlorinated compounds.

Stoeckeler, J.H., and G.J. Voskuil. 1959. Water temperature reduction in shortened spring channels of soutwestern Wisconsin trout streams. Trans. Am. Fish. Soc., 88(4):286-288. (ADF&G, Habitat Library, #R5110.)

Late afternoon summer water temperatures at the mouth of a spring channel on a trout stream near La Crosse in southwestern Wisconsin were reduced by 10 to 11°F by shortening the channel by 67% and routing the water through a willow-shaded location. (Author's abstract)

Activity: channelizing waterways.

Impact: change in water temperature.

Striffler, W.D. 1960. Streambank stabilization in Michigan - a survey. USDI: Forest Service Res. Pap. 84. Lake States Forest Exp. Station, Lansing, Michigan. 14 pp. (ADF&G, Habitat Library, #B1771.)

A survey of streambank stabilization in northern Lower Michigan was made during the summer of 1958. Data were collected and analyzed from 113 untreated and 115 treated banks on three treated watersheds and one untreated watershed, with the following results:

1) Bank stabilization is highly effective in stabilizing waterlines, reducing bank erosion, and increasing the density of the vegetative cover. Serious erosion on treated banks averaged 7%, compared with 47% on untreated banks. Waterlines of treated banks were 93% stabilized, compared with 28% on untreated banks. The density of the vegetative cover on treated banks averaged 50%, compared with 26% on untreated banks.

2) Of the physical bank features examined, only the texture of the soil bore any consistent relationship to the stability of the bank. Clay banks generally had more serious erosion, less stabilized waterlines, and less ground vegetation. Sand and clay banks both responded to treatment to the same degree.

3) After the banks were well stabilized by planting, volunteer vegetation usually took over from planted vegetation.

4) The success of stabilization was adversely affected by cattle grazing or trampling or the recreational use of the bank. Fencing the bank to exclude cattle is of utmost importance. (Author's summary)

Activity: channelizing waterways; filling (aquatic and wetland habitats); grazing; human disturbance.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; physical trampling or crushing.

Sumner, F.H., and O.R. Smith. 1940. Hydraulic mining and debris dams in relation to fish life in the American and Yuba rivers of California. Calif. Fish Game 26(1):1-22. (ADF&G, Habitat Library, #R2841.)

This article describes impacts of dams designed to contain and settle out sediment from gold-mining effluent waters on spawning populations of salmonids. The technique of building debris dams described in this article is no longer practical. Earthen dams have replaced concrete; however, the impact of sediments and the physical impedance created by these dams are the same.

Early mining and later construction of dams greatly reduced the salmon runs in the American and Yuba rivers by blocking anadromous runs of steelhead and salmon.

Observations are described that indicate muddy water reduces salmonid spawning activity. Preliminary sampling demonstrates that clean substrates produce more fish-food organisms than do substrates silted from mining activity. (Author's summary: partial)

Activity: processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Suter, G.W. 1978. Effects of geothermal energy development on fish and wildlife. USDI: USFWS - Office of Biological Services, Washington D.C., Publ. No. FWS/OBS-76/20.6. 20 pp. (ADF&G, Habitat Library, #B1922.)

This document discusses the nature of geothermal resources, technologies for exploration, extraction, and use; effects (primary impacts) of these activities on fish and wildlife; and the potential for habitat enhancement. Emphasis is placed on the range of possible activities and effluents, including comparisons with other energy technologies.

Three types of geothermal resources are being utilized or may be utilized as energy sources: hydrothermal, geopressured, and hot dry rock. Hydrothermal resources consist of stream or water heated by volcanic material that has intruded into the earth's mantel. Geopressured geothermal resources consist of hot water isolated in poorly consolidated sandstones by subsidence (a decline in elevation of a portion of the earth) along growth faults (resulting from the slumping of rapidly deposited sediments) in deep young sediments. Hot dry rock resources consist of areas with higher than normal heat flow gradients but no suitable aquifer.

Primary impacts are presented in text, and the reader must deduce how these will affect a particular species. Impacts mentioned include loss of habitat through road development, well drilling, transmission-line corridors, pipeline construction, dredging and filling wetlands, noise, human presence, physiological stress, erosion, sedimentation and dust. An increased demand for water for drilling and condenser cooling for electrical generation can be expected.

Common chemical constituents of gases and liquids from geothermal and hydrothermal wells and processing plants are discussed. Noncondensible gases in geothermal fluids vary widely. Gas fraction of steam at operating geothermal developments have been found to contain CO_2, H_2S, CH_4, NH_3, N_2, H_2, C_2H_6, He, Ar, Ne, Hg, Rn. The emissions of cooling systems for geothermal plants are higher per megawatt of electricity than those of coal or nuclear plants. Drift deposition of contaminants in these emissions is a potential problem. Other potential problems may arise from improper methods of disposal of geothermal plant liquids. These liquids may contain contaminants which are toxic to some aquatic organisms. Many of these would still exceed toxic levels after a thousandfold dilution. The toxicity problem is complicated by synergistic interactions among toxicants and between toxicants and temperature. Geothermal fluids have temperatures greater than 100°C; upper lethal temperature levels for a variety of freshwater fish range from 23.5-28.6°C. The low thermal efficiency of geothermal plants results in relatively high environmental heat loads. Once-through cooling of a geothermal plant would have large effects per megawatt of electricity due to heat, entrainment (passage through the system of smaller organisms), and impingement (capture on screening device of cooling water intakes of larger organisms).

Activity: drilling; processing geothermal energy.

Impact: change in water temperature; change in turbidity or suspended sediments; impingement or entrainment or entanglement; change in levels of other toxic compounds - sulfurous compounds; change in levels of other toxic compounds - other.

Sutterlin, A., M. Sutterlin, and S. Rand. 1971. The influence of synthetic surfactants on the functional properties of the olfactory epithelium of Atlantic Salmon. Fish. Res. Bd. Can. Tech. Rept. No. 287. 14 pp. (ADF&G, Habitat Library, #B0830.)

Over 150 synthetic surfactants were tested for stimulatory effectiveness and possible blocking effects on the sensory discharge evoked by amino acids in the olfactory epithelium of Atlantic salmon parr. Few surfactants were stimulatory at 1 and 10 ppm and no trends were apparent relating stimulator effectiveness to certain classes of these compounds. Blocking effects at 1 ppm and lower were observed for several alkyl-benzenesulfonates, quaternary ammonium and imidazolinium salts and diamines. Most blocking effects were reversible following rinsing with clean water. Nonionic surfactants exhibited no blocking effects. (Author's abstract)

Activity: sewage disposal.

Impact: change in levels of other toxic compounds - other.

Swales, S. 1982. Environmental effects of river channel works used in land drainage improvement. J. Environ. Manage. 14:103-126. (ADF&G, Habitat Library, #R3853.)

The effects which river channel works such as dredging, widening and straightening, used in land drainage improvement, may have on physico-chemical environmental characteristics and the nature of the aquatic community are discussed, with particular emphasis being placed on fish habitat and ecology.

It has been shown that channel works can be completed with the mimimum of environmental disturbance. Channel modifications can be carried out without extensive bank vegetation removal or serious damage to the river ecosystem. It has also been demonstrated that it is possible to mitigate the adverse effects of river channel works using instream habitat improvement devices to recreate natural river characteristics. Structures such as current deflectors, low dams, and artificial cover structures have been employed successfully to rehabilitate areas of river affected by channelization and to restore fish population to pre-channelization levels. (Author's abstract and summary: partial)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation.

Swales, S., and K. O'Hara. 1980. Instream habitat improvement devices and their use in freshwater fisheries management. J. Environ. Manage. 10:167-179. (ADF&G, Habitat Library, #R5132.)

Fish distribution and abundance in rivers are largely determined by physico-chemical characteristics of the environment. The importance of physical factors associated with both longitudinal river zonation and local habitat variability are discussed in relation to their effects on fish populations.

Human disturbances to the river ecosytems may modify natural river channel morphology, producing conditions unfavourable to the survival of river fauna. However, instream structures may be used to mitigate the adverse effects of river channel works and to recreate natural river characteristics. Habitat improvement is largely achieved by using devices to impound or modify river flow, provide shelter, or improve spawning areas. (Authors' abstract)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - impoundments.

Swanson, F.J., and C.T. Dyrness. 1975. Impact of clear-cutting and road construction on soil erosion by landslides in the western Cascade Range, Oregon. Geo. July 1975, 393-396. (ADF&G, Habitat Library, #R3588.)

The H.J. Andrews Experimental Forest was divided into two zones of approximately equal area, each with strikingly different susceptibilities to erosion by rapid soil movements. A stable zone occurs at elevations above 900 to 1,000 m in terrain underlain by lava-flow bed rock. Since logging and road cutting began in 1950, only two small road-related slides have taken place in the stable zone. In contrast, the unstable zone, located at elevations below 1,000 m and underlain by altered volcaniclastic rock, has been the site of 139 slides during the same period.

Slide erosion from clear-cut areas in the unstable zone has totaled 6,030 m^3/km^2, or 2.8 times the level of activity in forested areas of the unstable zone. Along road rights-of-way, slide erosion was 30 times greater than on forested sites in the unstable zone; however, only about 8% of a typical area of deforested land in the unstable zone is in road right-of-way. At comparable levels of development (8% roads, 92% clear-cut), road right-of-way and clear-cut areas contribute about equally to the total impact of management activity on erosion by landslides in the unstable zone. The combined management impacts in the unstable zone (assuming 8% road right-of-way and 92% clear-cut) appear to have increased slide activity on road and clear-cut sites by about five times relative to forested areas over a 20 yr period. (Author's abstract: modified)

Activity: clearing and tree harvest; grading/plowing.

Impact: physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation.

Swanson, F.J., and G.W. Lienkaemper. N.d. Physical consequences of large organic debris in northwest streams. Unpubl. rept., Oregon State Univ., Corvallis, OR. 14 pp. (ADF&G, Habitat Library, #R2322.)

This paper discusses the mechanisms by which large organic debris enters into and moves in streams, the consequences of debris movement on channel morphology and sediment routing, the habitat characteristics of debris in streams, and the impact of management activities on stream debris. A case study of an Oregon coastal stream is presented.

The authors summary includes the following:

Large organic debris is a principal factor determining the biological and physical character of small and intermediate-sized streams in forested landscapes of the Pacific Northwest. Debris enters streams by blowdown, undercutting of streambeds, and mass movement processes on adjacent hill slopes. Debris is moved through channels by flotation at high water, in torrents, and as dissolved and fine particulate matter following the breakdown of wood-processing organisms.

Water and sediment routing in channels is controlled by large debris, which may create a stepped along-stream profile. Stream energy is thereby dissipated at the relatively short, steep sections of channel so that much of the stream area may have a gradient less than the overall gradient of the valley bottom.

Debris in streams creates habitat for aquatic organisms both by serving directly as a substrate and by modifying streamflow to form depositional areas. Activity of consumer organisms tends to be concentrated in areas of wood and wood-created habitat. In undisturbed first-order streams, this area may exceed 50% of the total stream area, and in third-order streams it may exceed 25%.

Large pieces of debris reside in streams for decades and even longer than a century. This long residence time results in a rather uniform level of debris concentration in streams during the 100+ yr of stand recovery following wildfire.

Management activities directly alter debris loading by addition or removal of material and indirectly by increasing the probability of debris torrents. The importance of debris avalanches in triggering debris torrents suggests that torrent prevention is best practiced by minimizing hillslope failures rather managing stream debris. Natural debris torrents occur in forested areas; however, clear-cutting and road construction may increase the frequency of debris torrents by 20 to 40 times. Repeated logging along headwater streams without buffer strips will prevent small streams from recovering large organic debris loads typical of undisturbed streams.

A program to maximize future options for good stream management would involve 1) leaving the natural debris in channels and introducing a minimum of additional debris; 2) leaving a buffer strip to help minimize alteration of the stream area and to serve as a source of large debris for the stream in the future; 3) minimizing debris avalanche potential, hence debris torrent potential, by improved unit and road layout, development and maintenance.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; addition of physical barriers - partial obstructions.

Swanston, D.N. 1969. Mass wasting in coastal Alaska. USDA: Forest Service Res. Pap. PNW-83. Pacific Northwest Forest and Range Experiment Station. Juneau, AK. (ADF&G, Habitat Library, #B3840.)

Mass wastage is the dominant process of natural erosion and slope reduction in geologically youthful southeast Alaska. Steep slopes and excessive soil-water content are the principal causes of slide occurrence; destruction of natural slope equilibrium and stabilizing root systems are secondary factors.

Slope gradient alone characterizes the region as primed for mass movements of all types. Sections of almost every timbered slope exceed the natural angle of stability of the soil on them. Man's activities will aggravate such naturally unstable slope conditions. Therefore, the practical problem faced by land managers is the decision to accept the consequences of logging oversteepened slopes or to control the effects of these activities in order to minimize the occurrence of mass movements. Control may be done by application of direct methods of slope stabilization or avoidance of areas of known or expected instability.

Probably the most practical and direct management policy at present is avoidance of areas of maximum slide susceptibility. The lower limit of internal friction angles for soils commonly found on these slopes is known (about 34°). Slopes with gradients equal to or greater than this angle are highly susceptible to sliding particularly if they are severely disturbed. (Author's conclusions: modified)

Activity: clearing and tree harvest.

Impact: addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Swanston, D.N. 1970. Mechanics of debris avalanching in shallow till soils of southeast Alaska. USDA: Forest Service Res. Pap. PNW-103. Pacific Northwest Forest and Range Experiment Station. Juneau, AK. (ADF&G, Habitat Library, #B3841.)

Studies in the Maybeso valley show that the majority of debris avalanches and flows develop on slopes greater than 34° and are especially frequent around a critical angle of 37°. On an isosinal contour map of Maybeso valley, this angle is represented by the critical contour 0.6, the sine of 37°. Above this critical contour, sliding is imminent with the destruction or disruption of any cohesive forces acting to hold the soil in place. Below the critical contour is a zone of decreasing instability. The zone of instability thus defined is located principally in the deeper stream notches and in a narrow band near the 1,200-ft contour. The narrow band in the vicinity of maximum slide activity corresponds to the steep face of a till shoulder marking the upper limit of younger till.

By construction of an isosine map, or more simply mapping of slope angles, areas of general slope instability within a watershed can be located and the feasibility of applying preventive or control measures determined. If the area of instability is a bedrock cliff, no additional consideration need be given. If the area lies within some of the best timber stands, serious thought should be given to harvesting techniques and road construction in the critical area. (Author's conclusions)

Activity: clearing and tree harvest; grading/plowing.

Impact: physical disturbance of substrate materials.

Swanston, D.N. 1971. Principal mass movement processes influenced by logging, road building, and fire. Pages 29-39, in Forest land uses and stream environment. Proceedings of a Symposium, 19-21 October 1970, Oregon State Univ. USDA: Forest Service, Pac. NW For. and Range Exper. Stat., Juneau, AK. (ADF&G, Habitat Library, #R3852.)

Dominant natural soil mass movement processes active on watersheds of the western United States include 1) debris avalanches, debris flows, and debris torrents; 2) slumps and earth flows; 3) deep-seated soil creep; and 4) dry creep and sliding. A dominant characteristic of each is steep slope occurrence, frequently in excess of the angle of stability of the soil. All but dry creep and sliding occur under high soil moisture conditions and usually develop or are accelerated during periods of abnormally high rainfall. Further, all are encouraged or accelerated by destruction of natural mechanical support on the slopes. Logging, road building, and fire play an important part in initiation and acceleration of these soil mass movements. Road building stands out at the present time as the most damaging activity, with soil failures resulting largely from slope loading, back-slope cutting, and inadequate slope drainage. Logging and fire affect stability primarily through destruction of natural mechanical support for the soils, removal of surface cover, and obstruction of main drainage channels by debris. (Author's abstract)

Activity: burning; clearing and tree harvest; grading/plowing.

Impact: physical disturbance of substrate materials.

Swift, D.J. 1978. Some effects of exposing rainbow trout (Salmo gaidneri Richardson) to phenol solutions. J. Fish Biol. 13:7-17. (ADF&G, Habitat Library, #R3880.)

This paper describes experiments to investigate responses, such as urine flow rate (UFR), haematocrit, and uptake by the loss of phenol (C_6H_5OH) from different tissues and organs of rainbow trout to obtain more information on the physiological action of this poison under sublethal conditions.

Phenol at nonlethal concentrations in hard water had no effect on the urine flow rate or haematocrit of rainbow trout for exposure times of 24 h. Phenol was detected in the urine in a nonconjugated form, and unchanged phenol was also extracted from muscle, blood, and brain. Uptake of phenol into tissue was found to be rapid with an equilibrium concentration being reached in 3 h. Loss of phenol after exposure was as rapid. The equilibrium concentration for muscle was similar to the phenol concentration to which the fish were exposed. Blood and brain contained smaller amounts. Close to or above the lethal threshold concentration (48 h LC_{50} 9 mg/l; 15C) the fish had higher than ambient concentrations in their tissues, most notably in the brain. Above the lethal threshold there is evidence of a large uptake of phenol by erythrocytes. (Author's abstract: modified)

Activity: filling (aquatic and wetland habitats); processing oil/gas; sewage disposal; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Swindel, B.F., C.J. Lassiter, and H. Riekerk. 1983. Effects of different harvesting and site preparation operations on the peak flows of streams in _Pinus elliottii_ flatwoods forests. For. Ecol. Manage. 5:77-86. (ADF&G, Habitat Library, #R3839.)

Stream flows on three poorly drained and contiguous pine flatwoods catchments were monitored for 3.5 yr. One was left untouched. Pine timber from another was manually harvested at the end of the first year, residues were chopped, terrain was bedded, and pine seedlings planted - a minimum series of forest operations. The third was subjected to a maximum series of forest operations - harvesting of tree-length logs with heavy equipment, lightwood stump removal, burning, windrowing, discing, bedding, and planting.

Unlike the minimum series, the maximum series of forest operations significantly increased the peak outflows, particularly following windrowing. The increase was estimated to exceed sixfold immediately following windrowing and to decrease slowly and linearly with time thereafter. (Author's abstract)

Activity: burning; clearing and tree harvest; grading/plowing.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials.

Sykes, J.E., and J.R. Hall. 1970. Comparative distribution of mollusks in dredged and undredged portions of an estuary, with a systematic list of species. Fish. Bull. 68(2):299-303. (ADF&G, Habitat Library, #R3814.)

A survey of benthic mollusks in Boca Clega Bay, Florida, showed a much smaller number and variety of species in the soft sediments in dredged canals than in the predominantly sand and shell sediments in undredged areas. Samples contained an average of 60.5 live mollusks and 3.8 species in undredged areas and 1.1 individuals and 0.6 species in dredged canals. A list of mollusks collected in this survey and in past studies is appended. (Author's abstract)

Activity: dredging.

Impact: removal of substrate materials; physical disturbance of substrate materials; introduction or removal of species.

Tarplee, W.H., D.E. Louder, and A.J. Weber. 1971. Evaluation of the effects of channelization on fish populations in North Carolina's costal plain streams. North Carolina Wildlife Resources Commission, Raleigh, NC. 22 pp. (ADF&G, Habitat Library, #B1880.)

This research study was designed to determine the degree of damage, if any, to fish populations resulting from channelization, and to determine the rate of recovery, if the damage was significant.

The conclusions from this study were as follows:

1) The removal of forest canopy and stream cover by channelization can warm Coastal Plain streams having white, shifting sand bottoms to a temperature higher than that permitted by North Carolina State law.

2) Most channelized streams are extremely shallow, have a flat bottom, and contain few deep pools, whereas undisturbed natural streams are deeper and contain numerous deep pools.

3) The greatest single factor affecting a fish population appears to be the amount of stream cover.

4) Data indicate that natural streams have an average carrying capacity per surface acre in excess of three times that found in streams that have been channelized.

5) The average poundage of game fish per surface acre was over 400% greater in the natural streams than in the channelized streams.

6) Channelization appears to adversely affect game fish more than nongame fish.

7) The number of harvestable game fish ($\geq$ 6 in long) was reduced by more than 75% by channelization.

8) Natural streams produce larger fish than do channelized streams.

9) Invertebrate macrobenthos were reduced by 78.8% in volume following channelization.

10) The overall quality of streams, as based on species diversity, was reduced by 27.5% following channelization.

11) Species diversity increased with corresponding increases in cover and time since channelization.

12) Forty-six percent of the natural streams yielded fish populations greater than 100 lb/surface acre, whereas only 15% of the channelized streams had more than 100 lb/surface

acre.

13) Forty-six percent of the natural streams revealed gamefish carrying capacities greater than 50 lb/surface acre, whereas only 6.6% of the channelized streams had a gamefish carrying capacity in excess of 50 lb/surface acre.

14) There was a considerable increase in the diversity index between cover classes 2 and 3, indicating that stream quality increases proportionately to the amount of cover.

15) Fish populations, as represented by species diversity, in a channelized stream may recover to natural levels in approximately 15 yr, provided no further alterations of the stream bed, bank, forest canopy, or aquatic vegetation occur. (Author's conclusions)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Taylor, T.L., and J.F. Karinen. 1977. Response of the clam, Macoma balthica (Linnaeus 1758), exposed to Prudhoe Bay crude oil as unmixed oil, water-soluble fraction, and oil-contaminated sediment in the laboratory. Pages 229-237 in D.A. Wolfe, ed. Fate and effects of petroleum hydrocarbons in marine organisms and ecosystems. Proceedings of asymposium, 10-12 Nov. 1976, Seattle, Wash. New York: Pergamon Press. (ADF&G, Habitat Library, #R3700.)

The small clam, Macoma balthica (Linnaeus 1758), will likely be subjected to oil slicks layered on the mud and to water-soluble fractions (WSFs) of crude oil or oil-contaminated sediment. Groups of adult clams in or on their natural sediment were exposed in flow-through aquaria at 7-12C to various concentrations of Prudhoe Bay crude oil layered on the mud surface, the WSF of the crude oil, and oil-treated sediment (OTS).

Gentle settling of crude oil over clam beds had negligible effects on clams observed for 2 mo. The WSF and OTS of Prudhoe Bay crude oil inhibits burrowing and caused clams to move to the sediment surface. Responses were directly proportional to concentrations of WSF or amount of OTS. The 1-h and 72-h effective median concentrations of the WSF for the responses of burrowing by unburied clams and surfacing by buried clams were 0.234 and 0.367 ppm naphthalene equivalents, respectively. The interpolated amount of OTS needed for a 50% surfacing response within 24 h was 0.67 g OTS/cm^2.

Although short-term exposures of clams to the WSF of crude oil and OTS caused few deaths, behavioral responses of clams to oil may be of great importance to their survival in the natural environment. In these laboratory tests, many of the clams recovered, but in nature, clams that come to the sediment surface may be eaten by predators or die from exposure. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Thackston, E.L., and R.B. Sneed. 1982. Review of enviromental consequences of waterway design and construciton practices as of 1979. Prepared for Office, Chief of Engineers, U.S. Army, Tech. Rept. No. E-82-4. Washington, D.C. 92 pp. (ADF&G, Habitat Library, #B1885.)

A summary of this report is not possible because many different subjects are discussed and because each comment stands by itself and is not necessarily related to other comments in a logically progressive fashion. However, some conclusions are presented. Each of these conclusions has been stated earlier in this report, and most have been discussed in some detail. Therefore, they will simply be restated and highlighted without repeating the explanations or justifications.

Corps of Engineers waterway projects involve a number of environmental effects, and these are primarily the loss of aquatic and terrestrial fish and wildlife habitats caused by disruption or change of the natural environment, and the increases in turbidity and sediment load.

Channel modification causes many environmental effects, including elimination or reduction of bottom and edge habitat for aquatic life; drainage of wetlands and modification of terrestrial wildlife habitat; induced clearing of bottomland hardwood forests and other major land-use changes; increased in-stream temperature and turbidity; runoff, isolation, and silting in of oxbows and meanders; lowering of water tables; increase in flash-flooding downstream from the modified stream reach; and more rapid transfer of nutrients downstream for assimilation in lower stream reaches. Some of these affects can be reduced by good engineering design, such as excavating from one side only, careful placement of dredged material, placement of drainage and level-control structures at the lower end of cutoff meanders, and routing the channel around sensitive or highly productive areas.

Alternatives to channel modification have received more attention in recent years, but many of the suggested alternatives would not be effective or economical in achieving the locally desired goals of reducing damage to current development. The greatest promise seems to be for the use of modified design (as mentioned above) and construction methods, such as more use of hand labor, which may be suitable and effective in some areas. Additional work is needed to develop and document design criteria for these modified designs.

Few, if any, major studies have been done systematically and scientifically to compare the environmental effects resulting from alternate designs or methods of construction for the same type of project.

Additional systematic research should be conducted to determine the relative magnitude of various environmental effects resulting from either various engineering design decisions or various construction methods. (Author's conclusions: partial)

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; change in levels of nutrients.

Thomas, V.G. 1985. Experimentally determined impacts of a small, suction gold dredge on a Montana stream. N. Am. J. Fish. Mgt. 5:480-488. (ADF&G, Habitat Library, #R4276.)

A small suction dredge was operated experimentally on Gold Creek in Missoula County, Montana to determine the effects of dreding on aquatic insects and the bottom habitat. A 10-m section was dredged from bank to bank. Sampling was conducted before dreding and at upstream and downstream stations for control. The experiments were replicated at an upstream site. Significant changes ($P < 0.01$) in aquatic insect abundance were restricted to the area dredged; downstream areas were not affected ($P > 0.05$). Recolonization was substantially complete 1 mo after dredging. Intergravel permeability was not significantly changed by dredging ($P > 0.05$). Suspended sediment concentrations during dredging were highly variable. Suspended sediment discharge averaged a maximum of 340 mg/liter at the outflow and returned to background levels within 11 m. Impacts of suction dredging on the bottom fauna appeared to be highly localized. No immediate downstream impacts were recorded other than fine sediment depostion and movement of unstable gravel beds downstream during the next year's peak flows, filling a downstream pool. (Author's abstract)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials.

Thomas, R.E., and S.D. Rice. 1975. Increased opercular rates of pink salmon (<u>Oncorhynchus gorbushcha</u>) fry after exposure to the water-soluble fraction of Prudhoe Bay crude oil. J. Fish. Res. Bd. Can. 32:2221-2224. (ADF&G, Habitat Library, #R3698.)

The opercular rates of pink salmon (<u>Oncorhynchus gorbuscha</u>) fry were measured during 24-h exposure to sublethal concentrations of the water-soluble fraction (WSF) of Prudhoe Bay crude oil. Opercular rates increased significantly for as long as 9 and 12 h after exposure to WSFs prepared from oil-water solutions of 2.83 and 3.46 ppm. The increases in rates were proportional to increases in doses. Recording changes in opercular rates appears to be a suitable method for detecting sublethal physiological effects of hydrocarbon stress because the observed changes occurred at approximately 20% of the 96-h LC_{50}. (Author's abstract)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Thomas, R.E., and S.D. Rice 1979. The effect of exposure temperatures on oxygen consumption and opercular breathing rates of pink salmon fry exposed to toluene, naphthalene, and water-soluble fractions of Cook Inlet crude oil and No. 2 fuel oil. Pages 39-52 in W.B. Vernberg, A. Calabrese, F.P. Thurberg, and F.J. Vernberg, eds. Marine pollution: functional responses. New York: Academic Press. (ADF&G, Habitat Library, #R3697.)

Oxygen consumption and breathing rates of fry exposed to toluene and naphthalene began to increase immediately upon exposure and declined in later hours during exposure. Breathing rate reached maximum responses values at 2 or 4 h, whereas the oxygen consumption rates were greatest at 6 or 8 h of exposure.
All three concentrations of naphthalene (107, 70, and 45% of the 24-h median tolerance limit) resulted in significant increases in the opercular breathing rate of pink salmon fry ($P < 0.01$); whereas, of the four toluene concentrations (94, 69, 45, and 30% of the 24-h TLm), only the two highest resulted in a significant increase in the breathing rate. Breathing rate response was linear with does.

Although relatively few fish were used in the studies of oxygen consumption, the pattern of increased oxygen consumption along with increased breathing rates in each of the exposures indicates that increased breathing rate of pink salmon fry reflects increased energy demands. Oxygen consumption was greatest at about 6 h of exposure, about 4 h after the occurrence of maximum breathing rates. Apparently, as the fry became physiologically acclimated to the stress of the toxicant, they increased the efficiency of oxygen extraction, thus decreasing the need to move water across the gills and subsequent expenditure of energy.

The increase in breathing rates of naphthalene-exposed fry over control fry was much greater at the low temperature of 4° than 12°C. Control fry at 4°C had lower metabolic rates. However, the breaching rate response to hydrocarbons, as a percentage of controls, was much larger at 4° than at 12°C, indicating that hydrocarbon exposures at 4°C are more stressful than equivalent exposures at 12°C. (From Rice et al. 1984).

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Thomas, R.E., and S.D. Rice. 1981. Excretion of aromatic hydrocarbons and their metabolities by freshwater and seawater Dolly Varden char. Pages 425-448 in J. Vernberg, A. Calabrese, F.P. Thurberg, and W.B. Vernberg, eds. Biological monitoring of marine pollutants. New York: Academic Press. (ADF&G, Habitat Library, #R3699.)

The gills were the most important pathway for excretion of carbon-14 from ^{14}C-labeled naphthalene. Most of the carbon-41 excreted by the gills was still attached to the parent compound. About 10% of the excreted carbon-14 appeared in the cloacal chamber, mostly as metabolites. Less than 1% of the total carbon-14 was excreted in the urine, predominantly as metabolites.

Tissues retained a significant amount of carbon-14 at 24 h. Muscle contained large amounts of carbon-14, but because of its mass, the gall bladder had the highest specific activity. The brain also retained significant quantities of carbon-14.

Although more ^{14}C-labeled toluene was excreted and metabolized than ^{14}C-labeled naphthalene, more ^{14}C-labeled naphthalene was retained in the tissues. A lower percentage of the carbon-14 was recovered in ^{14}C-labeled naphthalene metabolites than in ^{14}C-labeled toluene metabolites.

Seawater and freshwater Dolly Varden char excreted similar amounts of carbon-14; however, the percentage of metabolites in the excretions and tissues of seawater fish was lower than the percentage of metabolites in excretions and tissues of freshwater fish. Fox example, we recovered greater amounts of carbon-14 with a lower percentage of metabolites from the brain-spinal cord of seawater fish than from the brain-spinal cord of freshwater fish--possibly explaining why seawater Dolly Varden char are more sensitive to aromatic hydrocarbons and the water-soluble fraction of oil than freshwater Dolly Varden. (From Rice et al. 1984)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Thomas, R.E., and S.D. Rice. 1982. Metabolism and clearance of phenolic and mono-, di-, and polynuclear aromatic hydrocarbons by Dolly Varden char. Pages 161-175 in W.B. Vernberg, A. Calabrese, F.P. Thruberg, and J.F. Vernberg, eds. Physiological mechanisms of marine pollutant toxicity. New York: Academic Press. (ADF&G, Habitat Library, #R3684.)

The objectives of this study were to determine and compare the effects of molecular weight and polarity on the clearance of several phenolic and aromatic hydrocarbons from gills and other excretory pathways of Dolly Varden char (Salvelinus malma) in sea water. The authors also examined the distribution of parent hydrocarbons and metabolites in tissues after 24 h of exposure. The hydrocarbons examined covered a range of structures, molecular weights, and partition coefficients. Two phenolic compounds, phenol and cresol, were examined. Toluene and naphthalene were chosen to represent common mono- and dinuclear aromatic hydrocarbons in water-soluble fractions of crude oil. Anthracene and benzo(a)pyrene were chosen to represent the larger, polynuclear aromatic hydrocarbons.

Results of the study showed that once hydrocarbons were absorbed from capsules placed in the gut of Dolly Varden char, size and polarity of the hydrocarbons influenced the elimination, metabolism, and tissue distribution. Size of the hydrocarbon appeared to be the most critical factor in excretion of hydrocarbons by the gills. Fish were found to easily excrete phenolicand mononuclear aromatic compounds through the gills. Some naphthalene was excreted from the gills, but none of the polynuclear aromatic hydrocarbons were excreted from the gills. Anthracene and benzo(a)pyrene excretion was minimal within 24 h. These compounds were slowly absorbed from the gut, had limited mobility between tissues, and were probably metabolized before excretion. Metabolism in the liver and secretion into the bile is probably the most important pathway for excretion of large molecular weight hydrocarbons; however, this is a relatively slow process that takes much longer than 24 h. (Authors' summary: modified)

Activity: drilling; filling (aquatic and wetland habitats); transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Thomas, R.E., and S.D. Rice. In press. Effect of pretreatment exposure to toluene and naphthalene on the subsequent metabolism of dietary toluene and naphthalene by Dolly Varden, Salvelinus malma. In W.B. Vernberg, A. Calabrese, F.P. Thurberg, and F.G. Vernberg, eds. Pollution and physiology of marine organisms. Univ. South Caroline Press. (ADF&G, Habitat Library, #R3705.)

Pretreatment exposure of Dolly Varden to naphthalene in sea water resulted in increased metabolism of orally administered ^{14}C-naphthalene, but pretreatment exposure to toluene did not alter the rate of metabolism of orally administered ^{14}C-toluene. Naphthalene is less polar than toluene and thus requires significant bioconversion before it is excreted by fish. Toluene is more polar and is readily excreted by fish, and inducement of increased bioconversion of toluene in the fish is, therefore, not needed.

Several pretreatment factors influenced the rate of naphthalene bioconversion, including 1) length of pretreatment exposure, 2) concentration of pretreatment exposure, and 3) duration of depuration after pretreatment exposure.

Pretreatment exposure of fish to naphthalene (75% of the 96-h LC_{50}) for 48 h doubled or tripled the percentage of naphthalene metabolites in brain, liver, and muscle tissue, and decreased the amount of carbon-14 recovered in those tissues. Pretreatment exposure for only 24 h caused some increases in tissue metabolites, but no significant differences in percent metabolites or tissue burden were measured between the pretreatment fish and controls, which were not pretreated.

The concentration of the pretreatment exposure is directly related to the increase in bioconversion rate of naphthalene. Exposure to 25 and 50% of the 96-h LC_{50} did not result in increased metabolism of naphthalene or in lower tissue burdens of the hydrocarbons. Exposure at 75% of the LC_{50} resulted in significant increases in tissue metabolites and decreases in total tissue hydrocarbon burden.

Periods of depuration following pretreatment exposure resulted in a decrease in the induced rate of metabolism of naphthalene. Depuration for as little as 24 h resulted in the return of the naphthalene bioconversion rate to that of control fish, which were not pretreated.

Pretreatment exposures of fish can induce increased metabolism of aromatic hydrocarbons, such as naphthalene, and may increase the survival of fish in subsequent exposures. Dinuclear and polynuclear aromatic hydrocarbons are quite lipophilic and must be metabolized before they can be readily excreted. Inducement of increased metabolism of these compounds resulting from a previous exposure increases excretion and, therefore, reduces hydrocarbon accumulation in the tissues of fish. (Author's summary)

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Thompson, A.J., and D.W. Paton. 1976. Exposure of chum salmon, Oncorhynchus keta, to copper in a controlled ecosystem experiment (CEPEX). Fish Mar. Serv. Res. Dev. Tech. Rept. 660. 28 pp. (ADF&G, Habitat Library, #B6264.)

Chum salmon fry, Oncorhynchus keta, were exposed to nominal copper concentrations of 2.5-5.0 mg/l over a period of 42 d in a controlled ecosystem. Samples were obtained at 2-wk intervals during the experiment. Gills and dorsal muscle from each fish were analysed for total copper content by atom reservoir spectrophotometry (graphite furnace). Statistical analysis of the data indicated that fish exposed to elevated copper concentrations accumulated significantly greater amounts of the metal in the gills when compared with controls. Copper data for the muscle samples exhibited only random fluctuations over the experimental period. The results suggest that copper concentrations of this magnitude, i.e., 10-20 times greater than ambient levels, are below threshold values required to promote bioaccumulation in the species tested. (Author's abstract)

Activity: dredging; grading/plowing; processing minerals.

Impact: change in levels of heavy metals.

Thurston, R.V., R.C. Russo, R.J. Luedke, C.E Smith, E.L. Meyn, C. Chakoumakos, K. Wang, and C.J.D. Brown. 1984. Chronic toxicity of ammonia to rainbow trout. Trans. Am. Fish. Soc. 113:56-73. (ADF&G, Habitat Library, #R3898.)

Results of a 5-yr ammonia toxicity laboratory study conducted at Montana State University during the period 1974-1979 are discussed in this paper. Parental rainbow trout (Salmo gairdneri) were exposed for 11 mo, the first filial generation for 4 yr, and the second filial generation for 5 mo to an environment of un-ionized ammonia concentrations that ranged between 0.01 and 0.07 mg/l. No significant correlation was found between ammonia concentrations and egg production, egg viability, or growth of progeny in any generation tested. Some individuals did develop lesions. Histopathological examination of the test fish showed adverse sublethal effects such as alterations in kidney and gill tissue. These abnormalities could lead to renal failure or impaired performance of the fish under conditions of reduced ambient dissolved oxygen.

Activity: processing oil/gas; sewage disposal.

Impact: change in levels of other toxic compounds - other.

Tiedemann, A.R., C.E. Conrad, J.H. Dieterich, J.W. Hornbeck, W.F. Megahan, L.A. Viereck, and D.D. Wade. 1979. Effects of fire on water: a state-of knowledge review. USDA: Forest Service Gen. Tech. Rept. WO-10. (ADF&G, Habitat Library, #B1167.)

In this report, the authors review and summarize the effects of fire on physical hydrology and hydrologic processes, both onsite and downstream from the fire-affected area. At the conclusion of the report research needs and priorities are identified and briefly discussed. A summary of the major points extracted from the literature are as follows.

1. Sedimentation, increased turbidity levels, and mass erosion appear to be the most serious threats to water resources following fire (especially wildfire). Elimination of protective streambank cover has been shown to cause temperature increases that might pose a threat to aquatic life.
2. Erosion responses to burning are a function of several factors, including degree of elimination of protective cover, steepness of slopes, degree of soil nonwettability, climatic characteristics, and rapidity of vegetation recovery.
3. Fire exerts pronounced effects on basic hydrologic processes, leading to increased sensitivity of the landscape to eroding forces and to reduced land stability. This is manifested primarily as increased overland flow, and greater peak and total discharge. These provide the transport force for sediment from the landscape.
4. Fire causes rapid mineralization and mobilization of nutrient elements that are manifested in increased levels of nutrients in overland flow and in soil solution. Watershed studies, however, indicate that these additional nutrients do not significantly impair the quality of surface waters for municipal purposes. Effects of nutrient losses via sediment and solution have not been related directly to site productivity but in general do not appear to represent a significant proportion of total site nutrient capitals.
5. Fire-caused water quality changes were not shown to adversely affect composition or productivity of benthic macroinvertebrates but this is a poorly documented research area.
6. Despite the lack of documentation of fire size and intensity, large fires of high intensity appear to have the greatest potential for causing damage to water resources. (Author's summary: modified)

Activity: burning.

Impact: change in water temperature; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; change in levels of nutrients.

Timbol, A.S., and J.A. Maciolek. 1978. Stream channel modification in Hawaii. Part A. Statewide inventory of streams, habitat factors and associated biota. USDI: USFWS. FWS/OBS-78/16. 157 pp. (ADF&G, Habitat Library, #B1221.)

There are at least 366 perennial streams in the five largest islands of Hawaii. Fifteen percent of these streams have been altered. Six types of channel alteration have been identified: lined channel, channel realignment and riparian clearance, elevated culvert, revetment, filled-in channel, and extended culvert. A total length of 151 km of these modifications has óbeen identified. The comparative "abundances" of these are as follows: lined channel, 40%; realigned/cleared, 28%; revetment, 24%; filled-in channel, 5%; elevated culvert, 3%; and extended culvert, less than 1%. Eighty-nine percent of the total length of lined channel is located on Oahu.

In terms of other human disturbances, only 14% of Hawaiian streams may be physically pristine, and none of these physically pristine streams is on Oahu, the most populous island in the state. There are apparently no longer any biologically pristine streams, because at least one exotic species was found in all streams sampled. Only 27% are of high-ecological-quality (pristine-preservation use), and none of these high ecological quality streams is on Oahu. Water is exported from 53% of all perennial Hawaiian streams.

Twenty-five species of fish and decapod crustaceans were collected statewide. Only eight of the species are native to the state. Both in numbers and biomass, native species are dominant in most unaltered streams, whereas exotic species are dominant in altered streams.

This report was submitted in fulfillment of Contract No. 14-16-0008-1199 by the Hawaii Cooperative Fishery Research Unit under the sponsorship of the Office of Biological Services, U.S. Fish and Wildlife Service. Work was completed February 18, 1978. (Authors' summary)

Activity: channelizing waterways; stream crossing - structures.

Impact: addition of substrate materials; alteration of natural cover - riparian vegetation; addition of physical barriers - partial obstructions; introduction or removal of species.

Toews, D.A.A., and M.J. Brownlee. 1981. A handbook for fish habitat protection on forest lands in British Columbia. Dept. Fish. and Oceans, Field Services Branch, Habitat Protection Division, Land Use Unit, Vancouver, B.C. 166 pp. (ADF&G, Habitat Library, #B1334.)

This publication provides an excellent review of pertinent literature related to the impacts of timber harvest practices on the aquatic environment and fish. Activities discussed include falling and yarding, forest roads, silviculture (including insecticide, herbicide, and fungicide use, slashburning, and fertilizer application), and log handling/transportation. Several case histories are related that show the effects of logging on streams. In addition, specific measures are provided for use in the planning process that should assist biologists in protecting aquatic ecosystems. Bibliographies at the end of each chapter serve as a good source of more detailed information concerning specific impacts. This publication is outstanding in its clear and concise presentation of such a large subject area.

Activity: chemical application; clearing and tree harvest; grading/plowing; log storage/transport.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; addition of physical barriers - partial obstructions; change in levels of biocides; change in levels of other toxic compounds - bark or log leachates; change in levels of nutrients.

Toews, D.A., and M.K. Moore. 1982. The effects of streamside logging on large organic debris in Carnation Creek. Dept. of Fisheries and Oceans, Habitat Protection Division, Vancouver, B.C. 29 pp. (ADF&G, Habitat Library, #B5103.)

The stability and volume characteristics of large organic debris in undisturbed and logged reaches of Carnation Creek were studied by comparing large-scale maps prepared annually for 4 yr before logging and 2 yr following logging. Three reaches that were logged were compared to two that remained unlogged throughout the study. The results showed that the debris is less stable, the debris volumes are similar or lower, the number of pieces is greater, and the average size is smaller following logging. These changes are the result of the removal and breaking up of stable in-stream debris and the addition of unstable debris during logging. The report presents preliminary data that indicate that coho fry populations initially increase as a result of the fine debris added immediately following logging but decrease with time as a consequence of channel alterations that resulted from the removal of stable debris. Streamside logging recommendations are presented that are directed towards maintaining the prelogging distribution and stability of organic debris. (Authors' abstract)

Activity: clearing and tree harvest.

Impact: change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; addition of physical barriers - partial obstructions.

Topinka J.A., and L.R. Tucker. 1981. Long term oil contamination of fucoid macroalgae following the Amoco Cadiz oil spill. In Amoco Cadiz, Fates and effects of the oil spill. Proceedings, international symposium, Centre Oceanologique de Bretagne, Brest, France, 1979. (ADF&G, Habitat Library, #R4326.)

Growth, biomass, tissue hydrocarbons and tissue nitrogen were examined in intertidal fucoid algae at nine sites along the coast of Brittany after the Amoco Cadiz oil spill. Gas chromatographic analysis of macroalgal tissue collected 14 mo after the initial spill disclosed that Fucus vesiculosus, F. spiralis, F. serratus, and A. nodosum from Aber Benoit and Aber Wrac'h remained the most heavily contaminated with oil. Higher levels of continuing oil exposure were associated with the biogenic production of pentadecane, the dominant resolved aliphatic component in fucoids. Total aliphatic material for all fucoids examined was 5-10-fold greater in Aber Benoit and Aber Wrac'h than in all the other areas and apparently contained considerable quantities of weathered oil. Growth rates of tagged F. vesiculosus 14-16 mo after the spill fell within the expected ranges. Relatively high growth rates in abers appeared to be associated with greater nitrogen availability. Although considerable damage to fucoid populations occured, in heavily oiled and subsequently cleaned areas, such as Ile Grande, populations are beginning to recover. Residual oil does not appear to be severely repressing fucoid reproduction or the survival of young plants.

Activity: transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Tornberg, L.D., E.D. Thielk, R.E. Nakatani, R.C. Miller, and S.O. Hillman. 1980. Toxicity of drilling fluids to marine organisms in the Beaufort sea, Alaska. Pages 997-1016 in Research on environmental fate and effects of drilling fluids and cuttings. Symposium Proceedings: Vol. 2, 1980 January 21-24, Lake Buena Vista, Florida. 1,122 pp. (ADF&G, Habitat Library, #B4660.)

Acute toxicity experiments were conducted in the field on arctic marine species, using various types of freshwater drilling fluids obtained from drilling rigs in the vicinity of Prudhoe Bay, Alaska. Organisms tested included amphipods, isopods, polychaetes, snails, mysids, fourhorn sculpins, broad whitefish, arctic cod, saffron cod, and arctic cisco. Test organisms varied widely in their responses to exposure to drilling effluents. For invertebrates, 96-h LC_{50} values ranged from greater than 60% for isopods, snails, and polychaetes to 22.1 to 38.1% for amphipods and 7.3 to 21.5% for mysids. Ninety-six-hour LC_{50} for all fish tested (fourhorn sculpin, broad whitefish, arctic cod, saffron cod, and arctic cisco) ranged between 4.0 and 40.0% (or greater). The resistant species are primarily sedentary, whereas more sensitive species generally have the capability of migrating into and away from a disposal site. Variations in drilling fluid characteristics appeared to produce variations in toxicities approaching those between different species. Amphipods demonstrated increases in total metals concentrations when exposed to various drilling fluid concentrations. The authors note that concentrations of drilling fluids likely to be encountered in Prudhoe Bay are 25% or less of the lowest values found in their experiments. They conclude that the mortality values calculated in their experiments are conservative. The authors state that acute effects to organisms exposed to drilling fluids are not expected in the arctic environment.

Activity: drilling.

Impact: change in turbidity or suspended sediments; change in levels of heavy metals; change in levels of hydrocarbons.

Trasky, L.L. 1976. Environmental impact of seismic exploration and blasting in the aquatic environment. ADF&G, unpubl. rept. 18 pp. (ADF&G, Habitat Library, #R2065.)

Trasky summarized information about buried seismic charges and their effects on fish. The most sensitive organ to an underwater explosion is the swim bladder. Fish with a swim bladder open to the alimentary canal (physos-tomatous) are not as sensitive as those with a closed one (physoclistous) because they may partially compensate for the pressure change. The fish usually sinks to the bottom when the air bladder bursts, so few dead fish are seen on the surface after an explosion. The shock wave that travels through the bottom may have a detrimental impact on fish eggs. Eggs are extremely sensitive to shock from the second day after fertilization until the pigment is formed in the eye. Any movement during this period can be fatal to the eggs.

Little information is available for shrimp, crab, lobsters, and oysters. These invertebrates seem fairly resistant to high pressures and most of the damage occurs from the very high pressures, cavitation, and intense shock wave close to the blast.

Trasky noted that except for salmon there are no references to pressure tests performed on different life stages of the same organism. One life stage may be more sensitive to pressure changes than another. Also, the magnitude and type of shock wave causing mortality to fish eggs has never been quantified.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Trautman, M.B., and D.K. Gartman. 1974. Re-evaluation of the effects of man-made modifications on Gordon Creek between 1887 and 1973 and especially as regards its fish fauna. Ohio. J. Sci. 74:162-173. (ADF&G, Habitat Library, #R5127.)

Gordon Creek, a tributary of the Maumee River in northwestern Ohio, was investigated by Meek in 1887, by Trautman in 1929-1938, by the personnel of the Ohio Division of Wildlife between 1954 and 1973, and by Trautman and Gartman in 1973. Dredging and ditching in this area were begun about 1850, continuing until the present, with major channelization occurring in 1935. Channelization, together with the effects of dams and pollution, has had a major effect on the fish species present in this stream.

The central mudminow (Umbra limi), grass pickerel (Esox americanus vermiculatus), golden shiner (Notemigonus crysoleucas), hornyhead chub (Nocomis bigullatus), mimie shiner (Notropis volucellus), tadpole madtom (Noturus gyrinus), and pirate perch (Aphredoderus sayanus) all require clean static or flowing water, rooted aquatic vegetation, sand and gravel substrates, and/or well-defined riffles and pools. These species have been largely reduced in population abundance or have been extirpated in part or entirely by the destruction of their habitats by channelization. In contrast, the creek chub (Semotilus atromaculatus), common shiner (Notropis cornulus), and spotfin shiner (Notropis spilopterus) are tolerant of a more or less uniform current flow, such as produced by channelization, and are therefore rather generally distributed and remain numerous. The siverjaw minnow (Ericymba buccata) and Johnny darter (Ethcostoma nigrum) were recorded in greatest numbers over gravel-sand substrates. The carp (Cyprinus carpio), fathead minnow (Pimephales promelas), bluntnose minnow (Pimephales notatus), common sucker (Catostomus commersoni), yellow bullhead (Ictalurus natalis), and green sunfish (Lepomis cyanellus) occurred most numerously in undredged pools or in pools largely recovered from former ditching: these pools were with or without currents, undercut banks, fallen timbers, and brush heaps, and had various types of substrates.

The largemouth blackbass (Micropterus salmoides), bluegill (Lepomis macrochrius), suckermouth minnow (Phenacobius mirabilis), and orange-spotted sunfish (Lepomis humilis), absent in 1887, have been inadvertently introduced or have invaded the area. In some sections, riffles and pools have become partially reestablished since the last channelization, resulting in isolated small populations of such species as the orange-throat darter (Etheostoma spectabile). (Authors' abstract)

Activity: channelizing waterways; draining; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; introduction or removal of species.

Trent, L., E.J. Pullen, and R. Proctor. 1976. Abundance of macrocrustaceans in a natural marsh and a marsh altered by dredging, bulkheading, and filling. Fish. Bull. 74(1):195-200. (ADF&G, Habitat Library, #R3819.)

Indices of abundance of macrocrustaceans during March-October 1969 in West Bay, Texas, were determined for day and night and statistically compared between 1) a natural marsh area, 2) upland and bayward canal areas of a housing development, and 3) an open bay area. Significance levels of 5% or 1% were used in the statistical comparisons. Catches of brown shrimp, _Penaeus aztecus_; white shrimp, _P_. _setiferus_; blue crab, _Callinectes sapidus_; and pink shrimp, _P_. _duorarum_, were significantly greater at night than during the day at one or more stations in the marsh. More grass shrimp, _Palaemonetes_ sp., were caught at night than during the day, but the differences were not statistically significant. Individuals of each species appeared to migrate into the more shallow areas of the marsh at night. At night, brown shrimp and blue crabs were significantly more abundant in the marsh and bayward canal areas than in the upland canal and bay areas, white shrimp were significantly more abundant in the marsh area than in the other three areas, and pink shrimp were significantly more abundant in the marsh than in the upland and bayward canal areas. During the day, brown shrimp were significantly more abundant in the bayward canal area than in the upland canal and bay areas, while pink shrimp were significantly more abundant in the marsh area than in the upland canal area. The generally lower catches of each species in the open bay and upland canal areas when compared with the marsh and bayward canal areas were attributed to 1) permanent loss of intertidal vegetation in the housing development; 2) low abundance of detrital material and benthic macroinvertebrates in the open bay and upland canal areas; and 3) eutrophic conditions in the upland canal area. (Author's abstract)

Activity: dredging; filling (aquatic and wetland habitats).

Impact: physical disturbance of substrate materials; alteration of natural cover - aquatic vegetation; addition of physical barriers - partial obstructions; change in levels of nutrients.

Tsai, C. 1970. Changes in fish populations and migration in relation to increased sewage pollution in Little Patuxent River, MD. Chesapeake Science 11(1):34-41. (ADF&G, Habitat Library, #R3894.)

This study was made to determine the changes in fish populations and their migration as a result of increased sewage pollution in the Little Patuxent River from 1958 to 1967. The upstream migration of white catfish, white perch, white sucker, and northern redhorse was apparently adversely affected by the increased sewage pollution. The downstream ranges and abundance of resident smallmouth bass and northern hog sucker decreased as did the upstream ranges and abundance of black crappie. Brown bullhead, golden-shiner, redbreast sunfish, and bluegill showed different degrees of changes in abundance without reduction in their distribution ranges.

Number of species and fish abundance decreased drastically in the area immediately below the chlorinated sewage effluents. The study strongly suggests that chlorinated sewage effluent caused the lowered fish populations below the sewage outfall and blocking of the upstream migration, rather than reduction in dissolved oxygen (DO) and pH (as a result of organic decomposition) or physical changes in the stream. The chlorinated sewage effluent consists of various compounds toxic to fish, such as ammonia, detergent, chlorine, chloramine, and perhaps others.

Farther downstream from the outfall, there were species and population rearrangements in each community without change in number of species. Those species sensitive to organic enrichment and low DO decreased in abundance or simply disappeared. They were replaced by other species tolerant to organic enrichment and low DO and able to increase in abundance.

Activity: sewage disposal.

Impact: change in water temperature; addition of physical barriers - other; change in level of dissolved oxygen, nitrogen; change in levels of pH, alkalinity, or hardness; change in levels of chlorinated compounds; change in levels of other toxic compounds - other.

Tsai, C. 1973. Water quality and fish life below sewage outfalls. Trans. Am. Fish. Soc. 102(s):281-292. (ADF&G, Habitat Library, #R3915.)

Comparative studies of water quality and fish species diversity in stream locations immediately above and below the outfalls of 149 secondary sewage treatment plants were made in Virginia, Maryland, and Pennsylvania. Water quality determinants included sampling for pH, water temperature, conductivity, turbidity, detergents, dissolved oxygen, total chlorine, ammonia, nitrogen, alkalinity, acidity, tota. phosphates, chloride, hardness, copper and zinc ions, nitrate and nitrates.

Sewage chlorine and turbidity increment resulting from sludge were found to be major causative factors for fish species diversity reduction below sewage effluent outfalls. Three types of sewage treatment plants and four types of outfalls were included in the study.

Activity: sewage disposal.

Impact: change in turbidity or suspended sediments; change in levels of chlorinated compounds; introduction or removal of species.

Tsai, C. 1975. Effects of sewage treatment plant effluent on fish: a review of the literature. Chesapeake Research Consortium Publ. No. 36. 229 pp. (ADF&G, Habitat Library, #B1171.)

The primary objective of this extensive review was to prepare a digest of the known effects of sewage treatmenet plant effluents on estuarine fish. However, since most studies (at the time of this review) have been devoted to freshwater habitats the author chose to include this literature as a background of essential literature to properly understand comparable effects of effluents in estuaries. The author reviewed numerous papers on sewage treatment effects on estuarine and marine fishes in the following categories: 1) sewage effluents - fisheries, reproduction and growth, behavior, diseases, pollution indicator; 2) residual chlorine - field and laboratory studies; 3) ammonia; 4) synthetic detergents; 5) hydrogen sulfide; 6) sewage sludges; 7) dissolved oxygen - lethal effects and destruction of fisheries, behavior, growth and reproduction, threshold concentrations; 8) toxic flagellates; and 9) fish culture. Interested readers should obtain this report for details on the specific effects of effluents on fish in each of the above subject areas.

Activity: sewage disposal.

Impact: change in level of dissolved oxygen, nitrogen; change in levels of chlorinated compounds; change in levels of other toxic compounds - sulfurous compounds; change in levels of other toxic compounds - other.

Tschaplinski, P. J., and G.F. Hartman. 1983. Winter distribution of juvenile coho salmon (Oncorhynchus kisutch) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Can. J. Fish. Aquat. Sci. 40: 452-461. (ADF&G, Habitat Library, #R3177.)

Numbers of juvenile coho salmon (Oncorhynchus kisutch) in streams are reduced substantially in winter compared to those that occur in summer. Most of this reduction occurs early in autumn with the onset of the first seasonal freshets. Stream sections containing adequate winter habitat in the form of deep pools, log jams, and undercut banks with tree roots and debris lost fewer fish during freshets and maintained higher numbers of coho in winter than sections without these habitat characteristics. These features provide shelter and reduce stream velocities. Microhabitats occupied by coho juveniles in winter after logging were unchanged from those described before logging - all microhabitats were characterized by low water velocities (less than or equal to 0.3 m/s). Up to 48% of the coho population inhabiting stream sections with adequate shelter remained there by midwinter (3 January). This percentage was typical of stream sections where at least some trees remained after logging. Streamside trees stabilized the banks and prevented their collapse. In contrast, two of three study sections that had been clear-cut logged had unstable banks that collapsed during winter freshets. Almost no coho remained in these sections in winter. Many coho emigrate from the main stream to seek the shelter of low-velocity tributaries and valley sloughs concurrent with the decline of coho populations in Carnation Creek during autumn and early winter. This seasonal shift in distribution reverses in the spring when large numbers of coho reenter the main stream. Fish overwintering in these sites have a high apparent survival rate. Before logging a 4-yr mean of 169 ± 44 coho entered one tributary (a slough called 750-m site) in autumn. Of these numbers entering, 72.2% came out in spring. During and after logging, an annual mean of 288 coho entered the same site. The apparent survival rate during and after logging was 67.4%, essentially unchanged from the prelogging value. Logging has neither reduced the numbers of coho juveniles that enter such sites in autumn to overwinter, nor reduced the numbers leaving these sites to reenter Carnation Creek in spring. (Authors' abstract)

Activity: clearing and tree harvest.

Impact: change in depth or velocity of water; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation.

Tyler, R.W., and D.R. Gibbons. 1973. Observations of the effects of logging on salmon-producing tributaries of the Staney Creek watershed and the Thorne River watershed and of logging in the Sitka District. Univ. Washington, Fisheries Research Institute, final rept., Part 1, FRI-UW-7307. Seattle, WA. 58 pp. (ADF&G, Habitat Library, #R2855.)

Preliminary data were gathered towards determining the effect of clear-cut logging on small, coho-producing streams of Southeast Alaska. The parameters measured during July on logged and unlogged tributaries in the Staney Creek Thorne River watersheds include water temperatures, abundance of juvenile coho salmon, insect abundance, concentrations of organic leachates, and gravel composition.

Preliminary findings were as follows:

1. Maximum stream temperatures occurred about 4:30 PM, 2.5 h after the peak of solar radiation.
2. Stream temperatures increased much more rapidly in logged than in unlogged study areas.
3. Juvenile coho and Dolly Varden char apparently were unharmed by temperature peaks that reached as high as 24.2°C (75.5°F), but that were of short duration.
4. As the result of a 6-d drought during which stream flows decreased by 50% and current velocities decreased by 75%, the exposure to solar radiation of stream waters flowing through unforested areas increased fourfold.
5. The removal of logging debris from rearing habitats, as is presently required, is important in maintaining adequate current velocity through clear-cut areas, thereby minimizing exposure to solar radiation.
6. The abundance of salmonids apparently declined by about half in both the logged and unlogged streams during the period July 16 through August 12.
7. Mayflies (Ephemeroptera) were the most abundant aquatic insects found in all study streams. The production of mayflies, caddisflies (Trichoptera), and miscellaneous flies (Diptera) was greatest in the logged streams.
8. The potential hazard to salmon spawning beds of log bridges not removed after logging was obvious on two streams into which road bridges had fallen, causing erosion and diversion of flow.
9. Root balls cause substantial erosion in streams that have been logged along the stream banks. Because the balls decompose very slowly in the stream, move readily with high water, and often ground on spawning bars, they affect the stability and productivity for decades after logging. (Author's abstract: partial)

Activity: clearing and tree harvest.

Impact: change in water temperature.

U.S. Army Coastal Engineering Research Center. 1977. Shore protection manual. U.S. Army Coastal Engineering Research Center. Fort Belvoir, VA. Vols. I, II, III. (ADF&G, Habitat Library, #B2078.)

This Shore Protection Manual incorporates knowledge of the scientific and engineering aspects of coastal processes and coastal and offshore structures. The manual is based on studies conducted on a continuous basis on shore processes and methods of shore protection by the U.S. Army Corps of Engineers since 1930. The manual is in three volumes covering guidelines and techniques for functional and structural design for shore protection works. Volume I describes the physical environment in the coastal zone; volume II translates the interaction of the physical environment and coastal structures into design parameters for use in the solution of coastal engineering problems; volume III contains a glossary of coastal engineering terms, a list of symbols, tables and plates, and a subject index.

Activity: filling (aquatic and wetland habitats).

Impact: addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; alteration of natural cover - overhanging bank or shoreline; change in level of salinity.

U.S. Army Corps of Engineers. 1981. Low cost shore protection. Dept. of Army, Corps of Eng., Contract No. DACW 61-81-D0012. Washington, D.C. 36 pp. (ADF&G, Habitat Library, #B1409.)

This report was prepared as a public service to demonstrate low cost erosion control measures in tidal-affected areas. Following a brief description of the natural processes affecting shorelines, the report describes several methods to protect the shoreline from erosion, and provides information on cost-effective planning and implementation of methods. The report contains several valuable pictures and diagrams that show how to implement various shore protection measures. The methods described apply to all protected and inland shores in the United States where wave height does not usually exceed 6 ft and severe storms or hurricanes are not annual events.

Activity: filling (aquatic and wetland habitats).

Impact: alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions.

U.S. Army Corps of Engineers. 1985. Final environmental impact statement: Auke Bay breakwater and related marina developments. Dept. of Army, Corps of Eng., Alaska District. Vols. I (FEIS), II (Appendices). (ADF&G, Habitat Library, #B6411.)

This document is a review of the Auke Bay 90 permit issued on November 6, 1981, under the authority of Section 10 of the Rivers and Harbors Act of 1899, to the Alaska Department of Transportation and Public Facilities. Included are reviews of interrelated permit applications for an expansion of a major private marina, for the construction of a small marina project, and for construction of a marina with an associated fill and dredge work, under the authority of Section 10 of the Rivers and Harbors Act of 1899 and also Section 404 of the Clean Water Act. The primary action is the decision to permit a proposed breakwater and transient moorage facility by the State of Alaska, and to permit the proposed expansion of private marinas in Auke Bay, near Juneau, Alaska. The purpose of the proposed projects is to relieve Juneau's unique demand for transient moorage and provide additional permanent or private moorage. Effects of the proposed projects on the natural environment relate to coastal wetlands, water quality, water circulation, invertebrates, fishes, marine mammals, and other biota in Auke Bay. Effects on the human environment are related to harbor management, traffic and parking, moorage capacities, freshwater supplies, research and education facilities, and visual/esthetic qualities for shoreside residents. (Authors' abstract)

Activity: filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions; change in level of salinity.

U.S. Dept. of Transportation. 1979. Restoration of fish habitat in relocated streams. U.S. Dept. of Trans., Fed. Highway Admin., U.S. Govt. Printing Office, Washington, D.C. 63 pp. (ADF&G, Habitat Library, #B3982.)

This manual provides guidelines for the design and construction of relocated channels and describes measures that will lead to rapid recovery of new channels by natural processes. Good design, and implementation of these measures can greatly reduce the adverse effects of stream relocation.

The literature on stream relocation and restoration is widely scattered in special reports and periodicallys of limited circulation. In 1976, under a contract with the Federal Highway Administration, Dr. James R. Barton, of Brigham Young University, examined the literature and made extensive field studies of channel relocations in 12 States. This manual has been developed by Dr. Barton from these researches. Mr. Frederick W. Cron, of Lakewood, Colorado, assisted in the preparation of the text. (Author's preface: partial)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

U.S. Environmental Protection Agency. 1973. Methods and practices for controlling water pollution from agricultural nonpoint sources. U.S. Envir. Prot. Ag., EPA-430/9-73-015, Washington, D.C. 83 pp. (ADF&G, Habitat Library, #B5237.)

Water and wind erosion, use of plant nutrients and pesticides, livestock management, cultivation practices, and leaching are important factors to consider in controlling water pollution. Because of the wide variations in topography, climate, types of soil, and patterns of crop and livestock production, no one method or practice is universally applicable. A combination of practices must be designed and selected to meet the situation for any particular farm or region.

Water Erosion: Soils are protected naturally by vegetation and vegetative residue. If moisture or fertility is too low, the land is subject to periodic erosion. Tilling the soil, overgrazing, crop harvesting, and burning of vegetation remove or bury portions of the protective organic material and may bring about more erodible conditions. this is particularly serious in areas of high rainfall.

Proper land use and agricultural management practices will keep soil, plant nutrients, and organic matter on the land, rather than allow them to become part of the water-borne pollutant load. Erosion may be reduced by means of conservation tillage, terraces, diversions, strip-cropping, contouring, grassed waterways, and crop rotations, and by more efficient range, pasture, and woodlot management.

Wind Erosion: Wind erosion is a relatively minor problem from the standpoint of water pollution, accounting for only a small fraction of the sediment loads in waterways. Major factors affecting wind erosion are soil cloddiness, surface roughness, soil moisture, vegetative cover, wind velocity, and field length along the prevailing wind direction.

Successful wind erosion control involves a combination of the following practices: 1) stubble mulch or conservation tillage practices to prepare land for crop production; 2) cover crops; 3) appropriate crop rotations; 4) controlled grazing; 5) wind barriers and shelterbelts; 6) artificial barriers; 7) hauled-in mulches; 8) emergency tillage; 9) deep plowing and 10) land forming and benching. These practices also conserve moisture and control water erosion.

Plant Nutrients: Agricultural operations have been identified as a potential contributor of nutrients to water resources. It is extremely difficult to identify the extent to which natural and applied plant nutrients may contribute to water pollution.

Factors influencing nutrient losses are precipitation and other sources of water, temperature, kind of soil, kind of crop, nutrient mineralization, and denitrification. Reducing nutrient losses from agricultural operations can be accomplished by three general approaches: 1) determining the proper amount, time, and method of plant nutrient applications to ensure efficient use by plants, 2) adopting approved cultural practices, including tillage and crop rotations, that minimize nutrient losses, and 3) reducing soil and water runoff by conservation measures such as contours and terraces.

Pesticides: The potential movement of chemical pesticides into water is of environmental concern. Most pesticides fall into three major categories: insecticides, herbicides, and fungicides. There are several approaches to reduce the quantity of pesticides entering surface and ground water. These include: controlling erosion and minimizing wind drift; reducing the quantity of pesticides used by applying minimum amounts needed, and/or substituting nonchemical methods of pest control; and using biodegradable rather than persistent pesticides, to the extent possible.

Animal Wastes: Disposal of animal wastes on land is a potential nonpoint source of water pollution. Animal wastes applied to land come from 1) wastes removed from feeding facilities, 2) contained runoff from feeding areas, and 3) excretion from animals on pasture and rangeland. Proper application of animals wastes provides nutrients for crop production and also reduces surface runoff. Appropriate animal and land management practices should be followed. These include: 1) spreading acceptable rates of manure uniformly on land; 2) applying feedlot runoff effluent on land as recommended for specific site conditions; 3) maintaining an adequate land-to-livestock ration on pastures; and 4) locating feeders and waterers a reasonable distance from streams and water courses. (Author's summary: partial)

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; change in levels of biocides; change in levels of nutrients.

U.S. Environmental Protection Agency. 1974. Evaluation of waste disposal practices of Alaska seafood processors. EPA-330/2-75-001. 335 pp. (ADF&G, Habitat Library, #B2101.)

This paper includes a description of waste disposal conditions at 26 Alaska canneries from June to August 1973. The results of the investigation indicated that scouring and dispersion by tides was the determining factor in the degree of treatment required. Dispersion was adequate to prevent deposits of discharged solids and associated water quality problems where 1) outfalls were situated in fast-moving tidal areas, 2) outfalls are submerged below lower low water, and 3) the wastes are ground before discharge. Bottom deposits and resultant water quality problems were observed where wastes were discharged (ground or unground) in quiescent or shallow waters or on beaches. These conclusions are followed by a list of proposed requirements for waste disposal by seafood processors in Alaska.

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials.

U.S. Environmental Protection Agency. 1975a. Forest harvest-regeneration activities and protection of water quality. Draft manuscript. USEPA, Region X, Seattle, WA. 340 pp. (ADF&G, Habitat Library, #B3969.)

This is a review document of logging residue management and reforestation activities. The study geographically covers Idaho, Oregon, Washington, and Alaska. Review is based on subregions of these states that comprise similar forest zones, hydrologic and meteorologic characteristics, land systems, and institutional constraints. The report discusses 1) harvest methods and forest management practices as they relate to water quality; 2) logging and transportation equipment systems and methods; 3) residue management practices; and 4) water quality protection as related to sedimentation and thermal and chemical pollution. A comprehensive bibliography follows the text.

Activity: log storage/transport.

Impact: physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen; change in levels of other toxic compounds - bark or log leachates.

U.S. Environmental Protection Agency. 1975b. Logging roads and protection of water quality. E.P.A. Region X, Water Division, Seattle, Washington. EPA 910/9-75-007. 313 pp. (ADF&G, Habitat Library, #B3868.)

The value of a thorough planning and reconnaissance program for a proposed road is emphasized by many authorities. No amount of design or construction expertise can recover from an approach based upon inadequate reconnaissance information. Field reconnaissance evaluations must include attention to the potential for mass movements as well as surface erosion. In steep terrain, it is likely that the engineering investment to insure a stable road will be much more exhaustive than on gentle terrain.

Many mass failures are drainage associated. Drainage design often appears to have lacked attention to one or more of the following features:

- Determination of the design flood
- Evaluation of the potential for debris blockage
- Choice of stream crossing method
- Attention to installation requirements at both the design and construction levels to insure structural integrity

Minimizing surface erosion and sediment transport begins with the appropriate treatment design of slope protection and continues with the necessary attention to ditch size, lining, culvert intakes, culvert integrity and culvert outlets. Under most conditions vegetative or other forms of permanent cover are essential to prevent excessive surface erosion from cut and fill slopes. Vegetation establishment should be initiated as soon after soils disturbance as possible. Various grass and legume seed mixtures are suitable for establishment of vegetation in Alaska depending on climatic and other environmental conditions. Seeding should be accompanied by fertilization and refertilization as necessary and by watering to maintain vegetative vigor.- Mulches, chemical soil stabilizers, or mechanical measures are necessary to prevent high initial rates of soil loss during vegetation establishment and in some cases to aid in vegetation establishment.

It is important to sequence the construction in a manner that affords the least exposure to storm damage during construction. Contractual relationships between owner and road builder should be such that a quick response can be made by all parties to changed circumstances during construction. Failure to respond promptly can greatly enhance the potential for sediment creation and transport. When construction is accomplished in accordance with adequate plans and specifications in a workmanlike manner under strict supervision, the minimization of sediment creation and transport may be coincident. (Author's abstract: partial)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials.

U.S. Forest Service, ADF&G, and ADNR. 1976. Logging and fish habitat. Informational Pamphlet, GPO 699-882. 21 pp. (ADF&G, Habitat Library, #B3473.)

This pamphlet was produced jointly by the Forest Service, and the Alaska State Departments of Fish and Game and Natural Resources. The pamphlet outlines guidelines for the protection of fish habitat. The following is a summary of practices that will help protect the fish habitat during and after logging:

1. Fall and yard timber away from streams when logging to stream banks.

2. Leave a fringe of windfirm timber along streams when necessary for stream protection.

3. Keep debris out of streams. If some does get into streams, remove it immediately.

4. Avoid skidding logs in or across stream beds.

5. Do not run equipment in the streams.

6. Use proper stream crossing bridges for equipment. Orient road-stream crossings at right angles to minimize erosion possibilities.

7. Do not yard across or out of V-notches if logs cannot be fully suspended above ground.

8. Properly engineer road grades, alignment, cutslopes, waste areas, and culvert and cross ditch locations. Install and maintain culverts properly.

9. Restore the original level of the streambed when removing temporary culverts.

10. Revegetate disturbed soil.

(Author's summary: modified)

Activity: clearing and tree harvest; grading/plowing; stream crossing - structures.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - partial obstructions.

USACRREL. (U.S. Army Cold Regions Research and Engineering Laboratory). 1980. Environmental engineering and ecological baseline investigations along the Yukon River-Prudhoe Bay haul road. [J. Brown and R.L. Berg, eds.] U.S. Dept. Trans., Fed. Hwy. Admin., Wash. D.C. 203 pp. (ADF&G, Habitat Library, #B4468.)

A 3-yr study was conducted to evaluate the performance of the Yukon River-Prudhoe Bay haul road and to assess changes in the adjacent environment associated with the road. Four major objectives were 1) to determine the rate and magnitude of thaw penetration and subsidence under and adjacent to the Haul Road; 2) to document existing flora, vegetation and soil types and determine the rate of change in plant communities, soil fauna, and soils due to natural and man-made surface disturbances; 3) to determine methods of enhancement restoration with native plant species; and 4) to characterize the annual air temperature and precipitation regimes along the Haul Road in order to provide the database required to substantiate environmental and engineering road designs. This report presents the results of road thaw subsidence and dust investigations, and summaries of revegetation, fuel gas line, vegetation distribution, soil, and weed studies.

Objectives of the roadbed investigations were to determine the magnitude of thaw under and adjacent to representative portions of the road and to determine the amount of roadway settlement at these same locations. Also, a survey of drainage problems associated with the Haul Road and performance of side slopes was conducted. The road traverses major portions of both the discontinuous and continuous permafrost zones. Results concerning roadbed, drainage, and side slopes associated with permafrost are as follows:

1) Seasonal thaw penetration probably exceeds the roadway embankment thickness in most locations. However, it probably does not penetrate the 1.7- or 1.8-m-thick embankment on the extreme northern end of the road and at other locations where the fill is in excess of 5 to 7 m thick. Seasonal thaw penetration into subgrade soils beneath the roadway embankment probably also exceeds the thickness of the active layer in adjacent undisturbed areas. This was the situation at all sites where subsurface temperatures were measured.
2) The roadway has subsided to some degree over nearly all of its length. Some of the "apparent subsidence" may be due to regrading of the road during maintenance operations, but at 11 of our 27 observation sites, the subsidence has been in excess of 10 cm and at 5 of these sites subsidence exceeded 20 cm. No strong relationship between subsidence, embankment thickness, and soil strength was apparent.
3) Ice-rich side slopes tend to stabilize from erosion after a few years, but thaw degradation and resulting subsidence continue beneath the ditches and roadway embankment. This was also the case along the trans-Alaska pipeline road.

4) The most frequent problem related to cross drainage was observed to be "maintenance clogging" of culverts. The problem occurred when short culverts were partially or entirely blocked by gravel pushed downslope from frequent grading, thereby preventing water movement through one or both ends of the culvert.
5) Thermal and hydraulic erosion downslope from the roadway was also associated with cross-drainage. This occurred on alluvial slopes along the Koyukuk River where gully erosion was induced by concentrating flow through culverts and onto ice-rich soils where nonconcentrated flow previously occurred.
6) Ponds of various sizes and depths formed due to the interception of lateral drainage by access roads that did not initially have culverts or low water crossings.
7) The major roadway surface drainage problem was the creation of small longitudinal dikes on one or both sides of the road due to regrading. These dikes inhibit lateral runoff except at locations where dikes are breached. Severe side-slope erosion can result where the breaches occur.

A summary of existing and proposed environmental guidelines applicable to road construction in arctic and subarctic regions is presented under the following categories: 1) minimization of impact during construction, 2) consideration of fish and wildlife, 3) criteria for drainage and erosion control, 4) the effect of road cuts in ice-rich soils, 5) stabilization of roadway embankments, and 6) criteria for revegetation and restoration.

Activity: clearing and tree harvest; draining; grading/plowing; stream crossing - structures.

Impact: change in water temperature; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation.

USFWS (Eastern Energy and Land Use Team). 1980. Summaries of riparian and stream alteration studies completed by the Eastern Energy and Land Use Team. USFWS, National Water Resources Analysis Group, Kearneysville, WV. 38 pp. (ADF&G, Habitat Library, #B3877.)

This document provides 36 abstracts of reports dealing with riparian and stream alterations. Most of these reports, however, are also summarized in this volume.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

USFWS. 1982. Handbook for protection of fish and wildlife from construction of farm and forest roads. Biological Services Program, FWS/OBS-82-18. 153 pp. (ADF&G, Habitat Library, #B1336.)

This document is intended to 1) provide a resource document that will assist state permitting authorities who are planning to assume Clean Water Act (P.L. 95-217) Section 404 permitting responsibilities with the identification of best management practices for construction and maintenance of farm or forest roads, which ensure that flow and circulation patterns as well as chemical and biological characteristics of the navigable waters are not impaired; 2) assist state and federal permitting authorities and resource, information, and education agencies in providing landowners and farm or forest road developers with support in planning and implementing best management practices that facilitate the protection and propagation of fish and wildlife resources during road construction and maintenance; 3) guide the planning, construction, and maintenance of farm and forest roads to comply with the permit exemption requirements of section 404(f)(1)(E) of the Clean Water Act of 1977; and 4) assist the U.S. Army Corps of Engineers and resource agencies during the review of permit applications and other resource development proposals in making practicable recommendations for the proper design of farm and forest roads.

This handbook describes 54 best management practices for planning, construction, and maintenance of farm and forest roads. Best management practices (BMPs) for planning road and facility layout and design, erosion control, construction and maintenance operations, and restoration to natural conditions, identified through existing state water quality management plans and management practices of federal agencies, were evaluated as to their environmental, institutional, technical, and economic effectiveness. Based on the results of the evaluation, BMPs were modified or augmented with other practices to enhance their overall effectiveness and to provide for protection and propagation of fish and wildlife resources. A discussion of purpose, description, performance, and limitations is provided for each BMP, and an approach is developed that guides handbook users in the selection of BMPs applicable to site-specific situations. (Author's preface and summary: modified)

Activity: grading/plowing; stream crossing - structures.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; alteration of natural cover - riparian vegetation.

Uthe, J.F., D.W. McLeese, G.R. Sirota, and L.E. Burridge. 1984. Accumulation of polycyclic aromatic hydrocarbons by lobsters (Homaurs americanus) held in a tidal pound. Can. Tech. Rept. Fish. and Aquat. Sci., No. 1059. iii + 10 pp. (ADF&G, Habitat Library, #B0435.)

This study followed changes in levels of polycyclic aromatic hydrocarbons (PAH) in lobsters held under typical summer and winter storage conditions in a commercial tidal pound. The tidal pound was constructed of creosote-treated timbers, which provided the source of hydrocarbon contamination. Results indicated that the levels of PAH in lobsters increased during 3-mo storage in the tidal pound. PAH concentrations in hepatopancreas and in tail muscle increased during impoundment, with more PAH accumulating when the lobsters were at higher (summer) than at lower (winter) temperatures. Summer-to-winter ratios of the PAH levels after 3-mo storage ranged from 2:1 to 19:1 for hepatopancreas and from 1:1 to 33:1 for tail muscle. Losses of PAH concentrations occurred when lobsters were transferred to clean water. Losses during 5 wk in winter ranged from 31 to 77% (mean 53%) in hepatopancreas and from 0-81% (mean 44%) in tail muscle. In summer, the results for depuration of PAH were variable.

Elevated PAH levels were measured in sediments within the tidal pound, and the authors related this to the creosoted lumber used to construct the structure. The authors provide no evidence that creosote structures that have been exposed to sea water for extended periods of time will still pose a threat to the aquatic environment. Creosote leaching is heaviest during the first year of exposure to sea water. However, contaminated sediment may be a continuing major source of PAH, but the extent and distribution (area and depth) of PAH-contaminated sediments in and around tidal pounds will require assessment before sediment removal can be proposed.

Activity: filling (aquatic and wetland habitats).

Impact: change in levels of other toxic compounds - other; change in levels of hydrocarbons.

VanHassel, J.H. 1979. Contamination of a salt-water stream ecosystem in southwest Virginia by highway-generated metals. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg. 25 pp. (ADF&G, Habitat Library, #B1972.)

Study of two sections of a stream associated with highways of different traffic densities near Roanoke, Virginia, and a third section used as a reference area demonstrated that concentrations of lead, nickel, cadmium, and zinc in sediments, benthic macroinvertebrates, and fish were highly correlated to the amount of traffic associated with the respective sampling site. Samples were collected in April, July, and November of 1978 and in February of 1979.

Highest sediment concentrations of lead, nickel, and zinc occurred in spring, most likely due to accumulation and subsequent runoff in snow. Accumulation of these metals in invertebrates and fish is probably a more time-dependent process. Concentrations in these organisms were related to physiological and ecological factors as well as to the relative availability of each metal at each study site.

The major physiological factor influencing accumulation of heavy metals in stream organisms seemed to be the relative amount of tissue with a high affinity for these metals in each organism. The major ecological factor influencing accumulation of heavy metals seemed to be the relative amount of sediment association characteristic of each species. Invertebrates contained the highest levels of each metal, followed by bottom-oriented fish with a small proportion of muscle, whereas species of fish with a large percentage of muscle inhabiting the upper water column contained the lowest concentrations.

Biomagnification of these four metals was not demonstrated. Significant bioaccumulation of lead, nickel, and cadmium in bone and cadmium in the kidneys of fish was found to occur. Major biological uptake of lead, nickel, cadmium, and zinc in these organisms was via water and/or sediment-water interaction. (Author's abstract)

Activity: transport personnel/equipment/material - land.

Impact: change in levels of heavy metals.

Varanasi, U., D.J. Gmur, and W.L. Reichert. 1981. Effect of environmental temperature on naphthalene metabolism by juvenile starry flounder (Platichthys stellatus). Archives of Environmental Contamination and Toxicology 10:203-214. (ADF&G, Habitat Library, #R3902.)

In this study, juvenile starry flounder maintained at 4 and 12°C were force-fed naphthalene. It was found that the lowering of the water temperature resulted in increases in both concentrations and residence times of naphthalene in starry flounder. Increases in concentrations at the lower temperature were much greater for naphthalene than for its metabolites. Lowering the temperature also altered relative proportions of the individual classes of metabolites accumulated in flounder tissues.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in water temperature; change in levels of hydrocarbons.

Viereck, L.A. 1983. The effects of fire in black spruce ecosystems of Alaska and northern Canada. Pages 201-220 in R.W. Wein, D.A. MacLean, eds. The role of fire in northern circumpolar ecosystems. John Wiley and Sons Ltd. (ADF&G, Habitat Library, #R5142.)

This paper does not directly relate to the effects of fire on the aquatic ecosystem. However, it discusses the effects on forest canopy alterations and their effects on soil characteristics that are linked indirectly to aquatic biota. Fire in the black spruce ecosystem of northern Canada and Alaska is characterized by large and frequent fires that usually kill the overstorey trees and most, if not all, of the vegetation aboveground. Most species within the black spruce ecosystem show adaptions to fire, and black spruce stands are usually perpetuated by fire. Depending on the site, revegetation follows one of two primary patterns, although under some conditions there may be intervening stages of birch, aspen, or lodgepole pine. In general, the succession on dry sites develops as open lichen woodland with a nearly continuous cover of fruticose lichens. On most sites, the development is that of a closed forest with a forest floor dominated by dense feathermosses and with a buildup of an organic mat. The final or climax vegetation that develops depends on site and climate and may vary from treeless bogs through feathermoss types to open lichen woodlands. In some areas, balsam fir replaces the black spruce. Fire reduces the organic layer on the forest floor and causes higher soil temperatures, an increase in available nutrients, and an increase in productivity for a period following the fire.

Activity: burning.

Impact: alteration of natural cover - riparian vegetation; change in levels of nutrients.

Viereck, L.A., and C.T. Dyrness. 1979. Ecological effects of the Wickersham Dome fire near Fairbanks, Alaska. USDA: Forest Service Gen. Tech. Rept. PNW-90. 71 p. (ADF&G, Habitat Library, #B6401.)

This report summarizes the abiotic and biotic ecological factors that were affected by a forest fire in interior Alaska. The evaluation of abiotic factors includes such topics as the effects of fire on forest floor characteristics, soil temperatures, permafrost, snow depths, overlying air temperature patterns, and stream water quality. Biotic factors include the effects on vegetation type, biomass, litter quantity, quality and decomposition rates, as well as effects in the distribution and abundance of arthropods, microtine rodents and snowshoe hares. The following paragraphs are portions of the authors' summary that pertain to the effects of fire on the aquatic ecosystem.

Unfortunately, little work has been done in interior Alaska on the effects of wildfire and fire suppression on quality of stream water. There are speculations that increases in erosion and runoff caused by fire are at a minimum in northern areas, but data to back this up are lacking. To obtain an indication of the effects of the Wickersham Dome fire on streams, sampling on Washington Creek was conducted both above and below the fire on the day the fire was controlled, 1 wk after control, and 2 wk after. The day the fire was controlled, suspended sediment content of the stream was about 300-500 mg/l. After the Bureau of Land Management constructed water bars on the firelines, the sediment content dropped to a maximum value of 19 mg/liter 1 wk after control. A small increase in concentration of phosphate in the stream water was measured after applications of retardants; however, concentrations of nitrogen were the same above and below the burned area.

In interior Alaska, one of the most important consequences of increases in soil temperature caused by fire is stepped up permafrost melting. Such thawing substantially increases the amount of available soil nutrients and soil water. On the Wickersham Dome fire site, change in the rate of thawing was particularly dramatic; 1 yr after the fire, the active layer was 62 cm thick in the burned area and only 42 cm in the unburned control. By the third year, the active layer had increased to 84 cm in the burned area and 47 cm in the unburned control. On firelines, where virtually all surface insulation had been removed, the rate of permafrost drop was almost doubled; 3 yr after the fire, the active layer in the firelines was 132 cm thick.

Despite substantial changes in the microclimate caused by fire, especially in and around the forest floor, studies of aboveground macroclimatic parameters did not disclose measurable differences between burned and unburned areas. For example, patterns of snow accumulation and snowmelt were not substantially different in a burned area than in an unburned area. Likewise, standard measurements of air temperature did not disclose a difference between burned and unburned areas. (Authors' summary: partial)

Activity: burning.

Impact: change in turbidity or suspended sediments.

Viereck, L.A., and L.A. Schandelmeir. 1980. Effects of fire in Alaska and adjacent Canada - a literature review. USDI: BLM, Anchorage, AK. Tech. Rept. 6. 124 pp. (ADF&G, Habitat Library, #B2476.)

Alaskan land and resource managers are moving from a policy of fire control to one of fire management. To use fire as a tool to reach resource management objectives, managers need information on fire effects and the role of fire in effects in Alaska and adjacent Canada, in both the northern forest (taiga) and the tundra. They report and interpret this literature, discussing fire effects information sources, fire history and fire regimes, and the effects of fire on soils, watersheds, vegetation, and animal life. They also point out information gaps that need to be filled.

Activity: burning.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; alteration of natural cover - riparian vegetation; change in levels of nutrients.

Vilks, G., C.T. Schafer, and D.A. Walker. 1975. The influence of a causeway on oceanography and foraminifera in the Strait of Canso, Nova Scotia. Can. J. Earth Sci. 12(12):2086-2102. (ADF&G, Habitat Library, #R3815.)

In 1955, a causeway was built across the Strait of Canso, Nova Scotia, Canada, preventing a free interaction between Gulf of St. Lawrence and Atlantic Ocean waters within the strait. The distribution of foraminifera in sediments was investigated in this study, to evaluate a possible impact of this barrier on the marine environment.

Data were collected from early May to late August 1973. During this period, the water on the Gulf of St. Lawrence side of the causeway was colder in early spring, but warmer and less saline during the summer as compared to the Atlantic side.

At the causeway, the surface 1-3 cm of the bottom sediments consists of very soft and black to dark brown mud on both sides. On the Atlantic side, these fine sediments cover bedrock; but on the Gulf of St. Lawrence side, they cover sands and gravels.

The 76 species of foraminifera collected in surface samples were subjected to cluster analysis which defined two distinct groups of stations separating the fauna on the two sides of the causeway. The characteristic species of the Gulf of St. Lawrence side is *Ammonia beccarii*.

In the subsurface layers the dominance of this species decreases with a zone extending 4 km to the north of the causeway. On this evidence it was concluded that prior to the causeway, the Atlantic waters extended at least 4 km further to the north. (Authors' abstract: modified)

Activity: filling (aquatic and wetland habitats).

Impact: change in water temperature; addition of physical barriers - partial obstructions; change in level of salinity.

Wagemann, R., B. Graham, and W.L. Lockhart. 1974. Studies on chemical degradation and fish toxicity of a synthetic tri-aryl-phosphate lubrication oil, IMOL S-140. Fish. and Mar. Ser. Tech. Rept. No. 486. 30 pp. (ADF&G, Habitat Library, #B6198.)

The toxicity of a commercial, synthetic tri-aryl phosphate lubricating oil, IMOL S-140, to rainbow trout, and the rate of hydrolysis of this substance were investigated. An approximate hydrolysis rate constant of 9 x 10-3/d and a half-life of 96 d for IMOL in fresh water were obtained. The contribution of phosphate to a natural water body from hydrolysis of IMOL is compared with the natural phosphate input from a watershed.

IMOL in water was not acutely toxic to rainbow trout, but prolonged exposure at concentrations of 0.3-9 mg/l of IMOL in water had an adverse effect on fish. In a 4-mo exposure period normal feeding was progressively impaired to the extent that towards the end of this period fish began to die. Enlarged livers, hardened fatty tissue, and a bluish discoloration of fatty tissue were observed in necropsied fish exposed to IMOL. The enzymes lactate dehydrogenase and glutamic oxalacetic transaminase were significantly higher in blood serum of fish exposed to IMOL compared with levels in unexposed fish. (Author's abstract)

Activity: transport personnel/equipment/material - land.

Impact: change in levels of hydrocarbons.

Wagener, S.M. 1984. Effects of placer gold mining on stream macroinvertebrates of interior Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 99 pp. (ADF&G, Habitat Library, #B6410.)

To determine the effect of placer mining on benthic macroinvertebrates, water quality characteristics and benthic invertebrates were sampled from nine hydrologically similar and proximally located streams that ranged from unmined control streams to heavily mined streams. Placer mining caused increases in turbidity, settleable solids, percentage of substrate embeddedness, nonfilter-able residue, and total recoverable arsenic, lead, zinc, and copper. Placer mining decreased invertebrate density and biomass and affected the community structure. Invertebrate communities in mined streams usually contained higher proportions of collector-gatherers and lower proportions of crawlers, shredders, filter-feeders, predators, and oligochaetes compared to unmined streams.

Activity: dredging; grading/plowing; processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; removal of substrate materials; physical disturbance of substrate materials; change in levels of heavy metals.

Washington Department of Fisheries. 1971. Criteria governing the design of bulkheads, landfills, and marinas in Puget Sound, Hood Canal, and Strait of Juan de Fuca for protection of fish and shellfish resources. W.D.F., Olympia, WA. 12 pp. + supplement. (ADF&G, Habitat Library, #B3370.)

This document states the guidelines presently used by Washington Department of Fisheries in design and construction of shoreline facilities, particularly bulkheads, landfills, and marinas. These criteria are based on sound biological data and act to supplement other requirements specified by local, state, or federal agencies in their review of these applications.

Activity: filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; change in level of salinity; introduction or removal of species.

Washington Department of Fisheries. 1974. Bulkhead criteria for surf smelt (Hypomesus pretiosus) spawning beaches in Puget Sound, Hood Canal, Strait of Juan de Fuca, San Juan Islands, and the Strait of Georgia. State of Washington, Dept. of Fisheries, Olympia, WA. 8 pp. (ADF&G, Habitat Library, #B3371.)

This document is a supplement to Washington Department of Fisheries (WDF). 1971. Criteria governing the design of bulkheads, land fills, and marinas in Puget Sound, Hood Canal, and Strait of Juan de Fuca for protection of fish and shellfish resources. The WDF is responsible for the management and protection of the surf smelt as a food fish. The original (1971) document did not include the particular needs of the surf smelt and hence was considered inadequate for the preservation of surf smelt spawning beach areas.

Surf smelt is a widely distributed and important resource in Puget Sound. It provides sport and commercial fishing, as well as providing an important forage for salmon and other fishes. Surf smelt deposit their eggs on the surface material in the upper intertidal zone of certain gravel beaches. This characteristic has made the species extremely vulnerable to encroachment onto beaches by development activities.

This document provides supplementary criteria that have been implemented as policy by the WDF in review of applications to construct bulkheading facilities. (Author's forward: modified)

Activity: filling (aquatic and wetland habitats).

Impact: addition of physical barriers - partial obstructions.

Watts, F.J. 1974. Design of culvert fishways. Univ. Idaho, Water Resources Research Institute, Moscow. 62 pp. (ADF&G, Habitat Library, #B5015.)

Types of fish migration and typical fish blockage problems associated with culverts are reviewed. Swimming capability of fish as a function of species (tables included), fish length, and water temperature are discussed. The hydrologic characteristics of streams and the importance of considering the timing of fish runs and peak discharge is reviewed.

A procedure for analyzing corrugated metal pipe and pipe arches for recommended swimming velocities is presented.

Slot orifice fishways for box culverts (slot orifice placed perpendicular to the flow and skewed wing-wall slot orifice) are discussed. Design aids developed for hydraulic analysis are presented. Instream construction in or near prime fish habitat is discussed.

Activity: stream crossing - structures.

Impact: change in depth or velocity of water; addition of physical barriers - partial obstructions.

Weber, P., and R. Post. 1985. Aquatic habitat assessments in mined and unmined portions of the Birch Creek watershed. ADF&G, Div. Habitat, Tech. Rept. 85-2, Juneau, AK. 65 pp. (ADF&G, Habitat Library, #B5966.)

The tri-agency placer-mining study team, comprised of representatives from the Alaska Departments of Environmental Conservation (ADEC), Natural Resources (ADNR), and Fish and Game (ADF&G), was formed in Fiscal Year 1985 to assess the effects of placer mining on aquatic resources and to provide management alternatives to protect those resources. This report presents the ADF&G component of the study: to assess the affects of mining on aquatic habitats.

Mined and unmined portions of streams in the Birch Creek watershed were inventoried to collect data on fish presence, habitat quality, and the densities and community structure of benthic invertebrates. The Birch Creek watershed includes both the Crooked Creek and Birch Creek drainages and is located in the Circle Mining District.

Placer mining in the Birch Creek watershed resulted in 1) elimination of the riparian vegetation, 2) increased particle embeddedness and a higher proportion of silt and sand deposited on the stream bottom below mining, 3) elimination of fish habitat, 4) depressed aquatic invertebrate populations, and 5) elimination of all fish from mined streams and from streams above active mining.

On the average, 45% of stream banks next to previously mined sites and 2.8% of stream banks next to unmined sites were devoid of vegetation. Stream bottom substrates were generally more embedded in fine silt and sand in sites below active mining than in sites above mining or unmined sites. Substrates in sites below active mining were an average of 41% embedded and substrates in control sites an average of 20% embedded. Study sites located below active placer mining areas contained one-tenth as many benthic invertebrates as sites either above mining or in unmined sites. An average of 7.5 invertebrates per 0.1 meter square ($0.1/m^2$) were found below active mining and an average of 71.2 invertebrates /0.1 m^2 in sites above mining and in unmined sites above mining. In contrst, an average of 27 fish were caught per 100-m reach in the unmined streams. Except for one round whitefish (<u>Coregonus nasus</u>), fish collected in the unmined streams were arctic grayling (<u>Thymallus arcticus</u>) and slimy sculpin (<u>Cottus cognatus</u>).

Activity: processing minerals.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Welch, H.E., P.E.K. Symons, and D.W. Narver. 1977. Some effects of potato farming and forest clear-cutting on small New Brunswick streams. Fish. Mar. Serv. Tech. Rept. 745, 13 pp. (ADF&G, Habitat Library, #B6109.)

A survey of 33 small streams (about 90 ha watersheds) in western New Brunswick was made in late summer 1974 to determine the effect of intensive agriculture and clear-cut logging upon fish, benthos, and physical characteristics of the streams.

Streams in clear-cut watersheds had 17% fewer trout, over 200% more sculpins, and 26% less benthos than control streams. Damage was attributed mainly to sedimentation, channelization, and to a lesser extent lack of riparian leave strips. Follow-up work indicated the importance of logging road crossings as sources of fine sediment and as areas where fish populations were altered.

Streams in farmed watersheds had 52% fewer trout, 92% fewer sculpins, and 64% less benthos compared with controls. Low numbers of fish and benthos were associated with chemical contamination, sedimentation being a contributing factor in all farmed watersheds. Additional work on a small river whose lower reaches drained farm land indicated young salmon were fewer and coarse fish more numerous in downstream reaches compared with those upstream; in the benthos, mayflies and stoneflies were fewer and chironomids more numerous in the region of agricultural runoff.

Damage from clear-cutting could be controlled with little effort, as could misuse of chemicals near streams. Sedimentation due to tilled land erosion would be more difficult to control. (Author's abstract)

Activity: clearing and tree harvest; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

Wesche, T.A. 1985. Stream channel modifications and reclamation structures to enhance fish habitat. Pages 103-163 in J.A. Gore, ed. The restoration of rivers and streams: theories and experience. Stoneham, MA: Butterworth Publ. (ADF&G, Habitat Library, #R5151.)

The underlying tenent of the river restoration approach is that by thorough planning done before modification activity begins, a design simulating that of nature as closely as possible can be developed that not only alleviates the problem causing the needed modification but also preserves many of the other valued reach characteristics. Too often in the past, the preservation of fish habitat, for example, was given little or no consideration until after the modification was completed. Later, when population levels were found to be declining due to the loss of habitat, attempts were made to artifically increase the carrying capacity of the reach by the addition of a variety of improvement structures. This is not to say that there is no place for structures such as wing deflectors or bank covers in habitat management. Rather, the point is that if proper planning had occurred during the design process, the need for these structures may not have been so great.

From a fisheries standpoint, a most simplistic view of the channelization process and associated impacts could be illustrated by the following flow diagram:

Δ Land and/or Stream Use -> Δ Channel Morphology -> Δ Hydraulics -> Δ Habitat -> Δ Population

where Δ = change in
-> = leads to

The key to the river restoration approach is for the habitat biologist to have input into the process prior to a change in channel morphology brought about by modification, rather than after the habitat and population changes have already occurred. The four fundamental components of salmonid habitat are acceptable water quality, food-producing areas, spawn-egg incubation areas, and cover. The extent to which each of these components is present in a given stream is dependent upon the stream's physical, chemical, and hydraulic characteristics. To provide a complete habitat, no matter how large or small the stream, requires the proper rate of flows through a suitable channel configuration, preferably one the stream itself has formed. It is in this regard that channelization activities have the potential to devastate a stream habitat, unless adequate planning and reclamation are carried out. (Author's introduction: partial)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.

Wesche, T.A., C.M. Goertler, and C.B. Frye. 1985. Importance and evaluation of instream and riparian cover in smaller trout streams. Pages 325-328 in R. Johnson, C. Ziebell, D. Patton, P. Ffolliott, and R. Hamre, eds. Riparian ecosystems and their management: reconciling conflicting uses. USDA: Forest Service Gen. Tech. Rept. RM-120. (ADF&G, Habitat Library, #R5147.)

Cover is an important trout habitat component resulting from the geomorphological characteristics of a stream channel, the stream bank interface with the riparian community, and the stream flow. This paper quantitatively describes the significance of the riparian contribution to overall stream cover as related to brown trout population size.

Activity: channelizing waterways.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Whitaker, G.A., R.H. McCuen, and J. Brush. 1979. Channel modification and macroinvertebrate community diversity in small streams. Water Res. Bull. 15:874-879. (ADF&G, Habitat Library, #R5111.)

The principal objective of this study was to investigate the long-term, temporal effect of channel modification in the diversity of macroinvertebrates. The study concludes that aquatic macroinvertebrate communities stabilize shortly after channel modification. This conclusion is based on correlation analyses, including five widely accepted diversity indices for stream reaches that have undergone channel work from less than 1 yr to more than 30 yr prior to the study. (Authors' abstract)

Activity: channelizing waterways.

Impact: change in turbidity or suspended sediments; physical disturbance of substrate materials; introduction or removal of species.

White, R.J. 1973. Stream channel suitability for coldwater fish. Pages 61-79 in Plants and animals and man. Proceedings of the 28th annual meeting, Soil Conservation Society of American, Sept. 30-Oct. 3, 1973. Hot Springs, Arkansas. (ADF&G, Habitat Library, #R5133.)

The author provides concise reviews for selected literature pertaining to the general habitat requirements of the various life-stages of salmonids as well as the effects of channelization and channel improvements on coldwater game fish. The section reviewing the importance of "cover" for fish and the section on channel improvements are particularly helpful. The author also includes a very helpful tabular summary of the literature on the quantative effects of channelization on salmonid populations.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

White, R.J., and O.M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Department of Natural Resources, Division of Conservation. Tech. Bull. No. 39. 65 pp. (ADF&G, Habitat Library, #B1895.)

This is a very good review of practical techniques for stream management to protect pristine habitat and improve damaged salmonid habitat. A review is provided of general management principals specific for trout stream habitat. These principals form the foundation for the practical guidelines that follow. The report has many helpful diagrams, illustrations, and photographs that are particularly helpful in visualizing the application of the proposed management guidelines. However, the report does not consistently provide documentation to support each guideline, and therefore it must be used with caution.

Activity: channelizing waterways.

Impact: change in water temperature; change in depth or velocity of water; addition of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

White, R.G., A.E. Bingham, R.A. Ruediger, and T.S. Vogel. 1980. Response of fish and fish-food organisms to reduction in stream discharge. Pages 480-493 in Western association of fish and wildlife agencies. 1980, western proceedings, 60th annual conference, Kalispell, Montana. 649 pp. (ADF&G, Habitat Library, #R3891.)

Experiments under controlled conditions were conducted in Idaho to examine the response of fish and aquatic insects to reductions in stream discharge. As discharge rates were reduced, an immediate increase in insect drift density and rate was observed as habitat conditions changed. Within 1 or 2 wk, drift densities in the reduced flow area returned to control levels, but drift rates were depressed in that area. No significant differences in total insect abundance was documented following reduced flow tests even though the drift indicated that insects were evacuating the area. The authors conclude that it appears that a major impact of reduced discharge is to reduce the availability of fish food (insects) in the drift.

Using steelhead/rainbow trout from both wild and hatchery populations, the authors examined the response of juvenile fish to reduced flow conditions by comparing emigration of stocked fish from the control (constant flow) and test (reduced discharge) areas. They conclude that it appears that even if a stream is not at carrying capacity, the trout population will respond negatively to reductions in discharge (i.e., emigrate from the systems).

Activity: water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water.

Whitney, A.N., and J.E. Bailey. 1959. Detrimental effects of highway construction on a Montana stream. J. Environ. Manage. 14:72-73. (ADF&G, Habitat Library, #R5112.)

In a small tributary stream (average flow of approximately 15 cfs) of the Columbia River drainage, a bulldozer was used to remove brush and straighten approximately 350 ft of stream for the purpose of highway construction. Based on data collected before and after the project (i.e., within the same year) it was shown that there was a 94% reduction on both numbers and weight of game fish (mostly salmonids) greater than or equal to 6 in long and 85 and 76% reductions in numbers and weight of game fish less than 6 in long.

Activity: channelizing waterways; grading/plowing.

Impact: alteration of natural cover - riparian vegetation.

Wilber, W.G. 1978. The influence of urbanization on the aqueous transport and distribution of heavy metals in the Saddle River. Ph.D. Thesis, Rutgus Univ., New Brunswick, New Jersey. 268 pp. (ADF&G, Habitat Library, #R4366.)

A study was conducted on the Saddle River near Lodi, New Jersey, to determine the sources and fates of heavy metals from street surface contaminants, crankcase oil, rainfall, and stormwater runoff. Lead and zinc was found in streetsweeping samples, especially in industrial areas. The concentration of heavy metals in the samples increased with decreasing particle size. Lead and zinc comprised over 99% of the metals in used crankcase oil. The main heavy metal components of stormwater runoff were lead, zinc, and copper. An average of 66% of the suspended solids in storm runoff settled out in 4 h. Lead and zinc were found in the solids fractions, whereas copper was mainly in the soluble fraction. Concentrations of heavy metals in the sediments of the river were quite variable. Less than 1% of the total metals in sediments, streetsweepings, and stormwater solids were soluble in river water. (Author's abstract: modified)

Activity: transport personnel/equipment/material - land.

Impact: change in levels of heavy metals.

Wildish, D.J., N.J. Poole, and D.D. Kristmanson. 1979. Pulp mill pollution in L'Etang estuary, a case history and clean-up alternatives. Fish. and Mar. Serv. Tech. Rept. No. 884, St. Andrews, N.B. 6 pp. (ADF&G, Habitat Library, #B0273.)

This study provides a chronology of events that has contributed to an accelerated reduction in water quality in L'Etang estuary. In 1967 a causeway was constructed that separated the upper and lower portions of L'Etang estuary. In 1971, a pulp mill became operational in upper L'Etang and began to discharge effluent wastes into the estuary. The causeway restricted tidal circulation in the upper L'Etang to such a degree that pulp waste degradation resulted in hypoxic conditions during 1971, and by the end of the summer of 1972, the water entirely lacked oxygen. During the summer of 1972, local residents and tourists complained about the smell of hydrogen sulfide gas in the area of the causeway. In 1973, the shellfish fishery was closed in both the upper and lower L'Etang because of high fecal coliform counts, apparently due to sewage produced at the pulp mill. This closure resulted in an estimated loss of 63% of the annual yield. In 1974, low catches of herring were reported in the lower L'Etang, but causes for the decline were not determined. From the point of view of aquatic resource management, the results emphasize the need for careful consideration of siting point source effluents, the further development of numerical simulation techniques for predictive purposes, and long-term planning for water resources.

Activity: processing lumber/kraft/pulp.

Impact: change in level of dissolved oxygen, nitrogen.

Wiley, R., and D. Dufek. 1976. Stream alteration and trout production. Wyoming Wildlife 41:30-31. (ADF&G, Habitat Library, #R5113.)

The Smiths Fork River in Wyoming is a moderate-size stream (average flow of 53 cfs) that drains an area of approximately 192 mi^2 and supports an important rainbow trout fishery. A portion of this river underwent channel straightening, instream cover removal, and bank clearing. A comparison between a natural reach and the channelized reach showed that the standing crop of trout was more than six times less in the channelized reach and that the average size of trout was also less in the channelized reach (6.7 and 7.4 in, respectively).

Activity: channelizing waterways.

Impact: alteration of natural cover - riparian vegetation; alteration of natural cover - aquatic vegetation; alteration of natural cover - overhanging bank or shoreline.

Wiley, M.L., and J.S. Wilson. 1975. Environmental effects of explosive testing. Appendix B In Experimental investigations of effects of underwater explosions on swimbladder fish, I: 1973 Chesapeake Bay tests. J.B. Gaspin. Naval Surface Weapons Center, Maryland. NSWC/SOL/TR 75-58. 40 pp. (ADF&G, Habitat Library, #B1243.)

Experiments were conducted in Chesapeake Bay using crabs (*Callinectes sapidus*), oysters (*Crassostrea virginica*), white perch (*Morone americana*), spot fish (*Leiostomus xanthurus*), and hogchoker (*Trinectes maculatus*). White perch and spot are fish with swimbladders, and the hogchoker has no swimbladder. The fish showed different susceptibilities to injury, which the authors ascribed to structural differences among the species. The species without a swimbladder sustained the least damage. Other structural differences that gave fish more protection were larger, thicker scales, heavier ribs and other skeletal features, firmer muscles and thicker walls in the gas bladder. Fish that survived the tests were sometimes able to recuperate, but the authors speculated that their injuries greatly increased their chances of being selectively eaten by larger fish. The authors were able to draw few conclusions from the tests with oysters and crabs. Some oysters and crabs were killed at the stations nearest the explosions but many survived.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Wilson, J. 1960. The effects of erosion, silt and other inert materials on aquatic life. Pages 269-271 in C.M. Tarzwell, ed. Biological problems in water pollution, transaction of the 1959 seminar. USDHEW, Robert A. Taft Sanitary Engineering Center, Cincinnati, OH. (ADF&G, Habitat Library, #R2907.)

This review paper discusses impacts resulting from the introduction to water-sheds of suspended sediments from eroding watersheds, gravel washing, road building operations, placer mining, deforestation, overgrazing, unwise irrigation, and other agricultural practices.

Increases in turbidity and siltation in an Oklahoma reservoir decreased the photosynthetic activity of algae and smothered most benthic organisms. Adult fish lived by feeding on smaller fish, but young of all species had little food until they were large enough to feed on other fish.

One study is cited that stressed the importance of maintaining a free flow of water through spawning gravels as a means of maintaining high dissolved oxygen content. Deposition of silt from an upstream source of land-wash or gravel-washing from mining operation, earth slides, road building, or deforestation destroys the eggs in spawning gravel by reducing the flow of water and thereby the necessary oxygen. Fine silt was found to interfere with gaseous interchange by coating the surface of eggs.

Activity: clearing and tree harvest; dredging; grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; change in level of dissolved oxygen, nitrogen.

Wilson, K.W. 1974. The ability of herring and plaice larvae to avoid concentrations of oil dispersants. Pages 589-602 in J.H.S. Blaxter, ed. The early life history of fish. New York: Springer-Verlag. 765 pp. (ADF&G, Habitat Library, #R3890.)

The responses of herring and plaice larvae to horizontal gradients of an oil dispersant (BP 1002) in sea water was studied in the laboratory. Direct avoidance responses were not observed. However, free swimming plaice larvae showed an almost instantaneous increase in swimming activity when exposed to the dispersant. Because of the increased activity, plaice larvae tended to move by random movements away from the area. Free-swimming herring larvae did not show any avoidance of vertical gradients, remaining in the dispersant layer until they became narcotized. The narcotized larvae sank into clean water but swam upward again when they recovered. Newly hatched plaice larvae did not sink, thus remaining in the dispersant layer. The author concludes that larvae would not avoid areas of dispersants at sea but because of the effects of dispersants would sink or swim away from lethal concentrations.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Wilson, K.W. 1976. Effects of oil dispersants on the developing embryos of marine fish. Mar. Biol. 36:259-268. (ADF&G, Habitat Library, #R2438.)

The effects of oil dispersants BP1002, Finasol ESK and Corexit 7664 on the development of herring, (Clupea harengus L.), plaice, (Pleuronectes platessa L.), and sole,(Solea solea L.) were studied. Treatment of developing embryos for 100 h with BP1002 and Finasol ESK gave rise to abnormalities in cell division and differentiation, to reductions in heart rate, eye pigmentation, growth rate, and hatching success above concentrations of 10 ppm. Larvae with abnormal flexures of the spine, which prevented them from feeding successfully, resulted from exposure to 5 ppm. Treatment of the embryos with dispersants throughout the period from fertilization to hatching (15 to 20 d) produced similar abnormalities at slightly lower concentrations. Corexit did not produce any demonstrable deleterious effects on embryos exposed to concentrations up to 5,000 ppm, the highest tested.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Wilson, K.W. 1977. Acute toxicity of oil dispersants to marine fish larvae. Mar. Biol. 40(1):65-74. (ADF&G, Habitat Library, #R2439.)

The acute toxicities of several oil dispersants to the larvae of haddock, herring, lemon sole, pilchard, plaice, and sole were examined, the type and aromatic content of the solvent being the main factors influencing the toxicity. Newer ("second generation") dispersants had much lower toxicities. Aging of dispersant solutions led to a decrease in toxicity, which could be related to loss of aromatic compounds from solution. Temperature and salinity had only a slight influence on toxicity. For all dispersants, differences of susceptibility between species were less than differences at different ages within a species. The larvae of all species showed a similar susceptibility when newly hatched, and susceptibility increased throughout the yolk-sac stage. The transition period from yolk reserves to an external food supply was most critical, for once larvae had established feeding, resistance increased until metamorphosis. The dispersants appeared to act largely as physical toxins causing a reversible narcosis. The implications of the results are discussed in relation to the use of dispersants at sea.

Activity: drilling; transport of oil/gas/water - water.

Impact: change in levels of hydrocarbons.

Winger, P.V. 1972. The effects of channelization and water impoundment on the macroinvertebrates in the Weber River, Summit County, Utah. Ph. D. Dissert., Brigham Young Univ., Department of Zoology. (ADF&G, Habitat Library, #B2835.)

Macroinvertebrate populations in the Weber River, Summit County, Utah, were analyzed to determine what effects channelization resulting from Interstate-80 construction and water impoundment had on the standing crop, species diversity, and species composition.

Bottom samples were collected monthly from riffle areas in channeled and unchanneled sections and above Echo and Wanship reservoirs. Macroinvetebrate populations in the channeled areas were similar in standing crop, species diversity, and species composition to those in unchanged areas within 6 mo following channelization. The colonization of the river bed was dependent upon the stability of the substrate, which was controlled mainly by the amount of water flow. High turbidity of the water below the channeled area occurred at and immediately following channelization, but normal levels were achieved in a short time.

This information should not be used as a rationalization for channelization; however, it does indicate that something can be done to salvage and rehabilitate already altered areas. However, much study needs to be conducted to determine the correct placement of structures and which structures are the most effective for a particular type of river condition.

Species diversities were higher (d=4.1, 3.7) above the reservoirs than below (d=2.0). The reservoirs restricted the distribution of several species of macroinvertebrates.

Drastic fluctuations in discharge from the reservoirs may be a factor causing the lower species diversity below them, especially below Echo Reservoir. The species diversity above Wanship Reservoir was 4.1; above Echo Reservoir it was 3.7; and below Echo Reservoir it was 2.0. These data indicate that the habitat above Wanship was a clean, natural habitat. The populations above Echo Reservoir are similar but showing some stress. Populations below Echo Reservoir have a lower species diversity, indicating some form of ecological stress. This indicates that the invertebrate composition and diversity of the Weber River are influenced by the presence of Echo and Wanship reservoirs.

Activity: channelizing waterways; water regulation/withdrawal/irrigation.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation.

Witten, A.L., and R.V. Bulkley. 1975. A study of the effects of stream channelization and bank stabilization on warmwater sports fish in Iowa: Subproject No. 2. A study of impact of selected bank stabilization structures on game fish and associated organisms. FWS/OBS-76/12. USFWS, Washington, D.C. 116 pp. (ADF&G, Habitat Library, #B6293.)

Four types of bank stabilization structures installed mainly for highway protection -- revetments, retards, permeable jetties, and impermeable jetties -- were studied during the summer and fall of 1974 to determine their impact on game fish habitats in Iowa streams. Stream width, depth, current velocity, water temperature, and turbidity were measured. Permeable jetties and retards deepened the channel near the structures. Maximum stream depth at or near these structures was from 7 to 110% greater than maximum depth in control sections of the streams. No other significant differences in physical parameters between structured and nonstructured sections of stream were found. Effects of bank stabilization structures on stream morphology (width and depth) and current velocity were difficult to assess. Most bank stabilization structures for highway protection are placed on concave stream banks, where the current velocity and stream depth are expected to be the greatest. Because it was impossible to duplicate the structure-area channel meanders in control areas, simple comparisons of current velocity and depth in structure areas vs. control areas did not give a totally accurate picture of the influence of the structure on stream morphology. It is difficult to separate the effects of the structures on stream morphology from natural variations in current velocity and depth. Soldier River permeable jetties, however, were on an almost straight reach of the river; large differences in depth between structure and control areas were found at these sites. The stream near the structures was significantly deeper than was the case in the control area. Revetments, which do not project into the stream but protect an existing bank, have no apparent effect on stream morphology. Neither retards or permeable jetties affected appreciably the maximum current velocities, but depths were greater near the structures. A long rock jetty, extending far enough into the stream to produce a scour hole, would combine most of the advantages noted for the structures studied. From the standpoint of habitat improvement, rock seems superior to steel as a construction material, and structures that cause the formation of scour holes are superior to those that do not deepen the stream. (Annotation from Stearn and Stearn 1980b)

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water.

Wolf, J., M. McMahon, and J. Diggins. 1972. Comparison of benthic organisms in semi-natural and channelized portions of the Missouri River. Proc. S.D. Acad. Sci. 51:160-167. (ADF&G, Habitat Library, #R5114.)

Channel straightening, instream dredging, and reduction of channel width of a section of the Missouri River decreased the benthic habitat diversity, which resulted in lowered production capability of benthic macroinvertebrates. Compared to seminatural channels, channelized reaches were primarily composed of main channel habitat and had almost no sand-shore, sand-bar, and cattail habitats, which supported nearly 4, 5, and 12 times the density of invertebrates than did main channel habitat, respectively.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; physical disturbance of substrate materials; introduction or removal of species.

Woods. L.C. 1977. The effect of stream channelization and mitigation on warmwater macroinvertebrate communities. Masters Thesis, Ohio State Univ. (ADF&G, Habitat Library, #B1775.)

This study evaluates taxonomic diversity, numbers, and biomass of macroinvertebrate drift and benthos in three habitat types in the Olentangy River, Ohio. The three habitats include 1) a natural reach, 2) a recently channelized reach (time since channelization not given) in which five artificial riffles were placed and along which the banks were revegetated and stabilized with riprap, and 3) an old channelized reach (more than 24 yr) for which no mitigation measures were employed. For the new and mitigated channel, no statistical difference was detected for numbers of families (diversity), numbers of organisms, or total biomass of benthic macroinvertebrates. However, natural and mitigated channels both had greater numbers of taxa, numbers of organisms, and total biomass than the old nonmitigated channel. Similar trends were evident for macroinvertebrate drift. Although no statistical differences were determined between natural and mitigated channel reaches for any of the three variables previously identified, both the natural and mitigated channels had significantly greater numbers of organisms and total biomass than the nonmitigated channel. Regarding numbers of families (diversity), the natural channel was shown to have significantly more taxa than the unmitigated channel, whereas no significant difference was determined between mitigated and unmitigated channels.

Activity: channelizing waterways; filling (aquatic and wetland habitats).

Impact: change in depth or velocity of water; addition of substrate materials; alteration of natural cover - riparian vegetation; introduction or removal of species.

Woodward-Clyde Consultants. 1980. Gravel removal studies in arctic and subarctic floodplains in Alaska. USFWS - Office of Biological Services, Washington D.C. Tech. Rept. No. FWS/OBS-80/08. 403 pp. (ADF&G, Habitat Library, #B4846.)

The primary purpose of this report is to provide information that will assist resource managers in minimizing detrimental environmental effects resulting from floodplain gravel mining. Data from 25 study sites in arctic and subarctic floodplains in Alaska were collected and analyzed by the following six disciplines: river hydrology and hydraulics, aquatic biology, terrestrial ecology, water quality, aesthetics, and geotechnical engineering. Included is a general overview that discusses the tradeoffs and comparisons between disciplines that must occur with respect to the siting, operation, and closing of material sites. Where possible, the similarities in approach of the various disciplines to minimize disturbance from gravel removal are emphasized because these conditions maximize protection of floodplain environments.

Major variables addressed include drainage basin size, channel width, channel configuration, channel slope, stream origin, type of gravel removal, and location of gravel removal. In regard to aquatic biota, gravel removal by scraping in floodplains resulted in a number of alterations to aquatic habitats. Important habitat alterations included 1) the creation of braided channel areas, with associated changes in various habitat parameters; 2) removal of bank and instream cover; 3) increased habitat diversity; 4) creation of potential migration blockages; and 5) creation of potential entrapment areas.

Activity: dredging; processing minerals.

Impact: change in water temperature; change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline; addition of physical barriers - impoundments; addition of physical barriers - diversions; change in level of dissolved oxygen, nitrogen.

Wright, T.D. 1978. Aquatic dredged material disposal impacts. U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss. Tech. Rept. DS-78-1. 57 pp. (ADF&G, Habitat Library, #B4871.)

The aquatic disposal field investigations described in this study were conducted at five representative locations at an Atlantic estuary, the open Gulf of Mexico, the Great Lakes, a Pacific estuary, and the open Pacific Ocean. In this review, findings from the Pacific estuary at Duwamish, Wash., and the open Pacific Ocean at the Columbia River will be discussed.

At the Columbia River dredging site there appeared to be no important chemical changes in the water column; however, disposal caused several biological changes. The number of benthic organisms present were reduced by burial with dredged material and the diversity increased. The reduction in numbers lasted for at least 8 mo after disposal, and the diversity increase lasted until the end of the study. The number of demersal fish and their species diversity were both lower after the dredge disposal, but recovery was noted several months later. The feeding habits of fish also changed after disposal; there was a shift from consumption of small prey items to larger ones.

At the Duwamish River disposal site, density, biomass, and diversity of benthic invertebrates were depressed after disposal. However, there was evidence that animals at the edges of the site were stimulated by dredged material. Bottomfish seemed to ignore the disposal site, whereas shrimp were attracted to the site.

Activity: dredging; solid waste disposal.

Impact: change in turbidity or suspended sediments; addition of substrate materials; change in levels of heavy metals; change in levels of chlorinated compounds; change in levels of biocides; change in levels of other toxic compounds - other; introduction or removal of species.

Wright, H.E. (Jr.). 1981. The role of fire in land/water interactions. Pages 421-444 in Proceedings of the conference on fire regimes and ecosystem properties. Gen. Tech. Rept. WO-26: Dec. 11-15, 1978; Honolulu, Hawaii. (ADF&G, Habitat Library, #R3889.)

Forest fires cause a temporary increase in runoff to streams and lakes, in part because of decreased evapotranspiration, according to studies in Washington (Entiat Fire), Minnesota (Little Sioux Fire), and Ontario (Experimental Lakes Area). Mass transport of nutrients and cations also increases, but no algal blooms were detected. Extent of fires is commonly limited by natural firebreaks provided by lakes and streams. The charcoal and pollen stratigraphy of annually laminated lake sediments provides a record of past fire frequency. Lake-sediment studies also document forest history over thousands of years, showing the shift from fire-adapted forests to fire-resistant forests, or the reverse. (Author's abstract)

Activity: burning.

Impact: change in depth or velocity of water; change in levels of nutrients.

Wright, D.G. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories - Canadian Tech. Rept. of Fisheries and Aquatic Science No. 1,052. 16 pp. (ADF&G, Habitat Library, #B4358.)

The use of explosives in the marine environment has been demonstrated to be harmful to both fish and marine mammals. Underwater shock waves resulting from the detonation of high velocity chemical explosives are potentially lethal to fish in that they can result in the rupture of the swim bladder and rupture and hemorrhage of the kidney, liver, spleen, gonads and sinus venosus. The high peak pressure, rapid rise times, and rapid decay to below ambient hydrostatic pressure are the properties of chemical explosives most damaging to fish. The presence of ice and type of bottom can change the rise time and peak pressure. Fish mortality increases with body weight, and the swim bladder is the main site of injury. Survival of eggs is greatly reduced with small charges of explosive. Larval fish are less sensitive to the effects of shock waves than are eggs or postlarval fish, where the swim bladder has developed. Wright cited a study in which newly hatched salmon and herring fry survived pressures of five bars and were apparently unaffected by rapid pressure changes. When the same fry reached 3 to 6 mo of age and developed a swim bladder, a pressure change of more than two bars caused mortality within 24 h.

Activity: blasting.

Impact: increase in hydrostatic pressure or noise.

Wu, T.H. and Swanston. 1980. Risk of landslides in shallow soils and its relation to clearcutting in southeastern Alaska. For. Sci: 26:495-510. (ADF&G, Habitat Library, #R3600.)

A significant increase in the frequency of landslides in shallow soils on hillside slopes of Southeastern Alaska following timber harvest by clear-cutting has been observed. This phenomenon relates to the loss of root strength and evapotranspiration stress that follows the cutting of the trees. A method for evaluating the landslide risk is described in this paper. A hillside with a nearly uniform slope is represented by an infinite slope, and the piezometric level required for shear failure is computed. A one-dimensional infiltration-seepage model is used to calculate the response of the piezometric level to rainfall. Weather data are used to calculate the probability of the piezometric level exceeding the value required for slope failure. Uncertainties in soil strength and slope angle may also be accounted for in the calculation of failure probability. Field data obtained from a site near Hollis, Alaska, are used to illustrate the method of risk evaluation and cost analysis. (Author's abstract)

Activity: clearing and tree harvest.

Impact: addition of substrate materials; physical disturbance of substrate materials.

Wydoski, R.S. 1978. Response of trout populations to alterations in aquatic environments: a review. Pages 57-92 in J.R. Murry, ed. Proceedings of the wild trout-catchable trout symposium, 1978; Eugene, OR. (ADF&G, Habitat Library, #R5129.)

The first half of this paper presents a series of concise reviews of the literature dealing with the effects of various types of developmental activities on aquatic environments in North America. The activities specified include logging, grazing, channelizing, dams, mining, dredging, and agricultural practices. A key-word index is included for the approximately 250-300 references cited.

The second portion of the paper is a review of the general ecology of streams and the effect of stream conditions on trout populations. The effects of streamflow, water quality, water temperature, and riparian vegetation on fish are briefly reviewed.

Activity: channelizing waterways; clearing and tree harvest; dredging; grazing; processing minerals; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; change in turbidity or suspended sediments; physical disturbance of substrate materials.

Wydoski, R.S., and W.T. Helm. 1980. Effects of alterations to low gradient reaches of Utah streams. USDI: USFWS; FWS/OBS-80/14. 160 pp. 160 pp. (ADF&G, Habitat Library, #B1820.)

This report is an investigation of the physical and biological effects of stream channelization in northern Utah. Erosion and deposition of streambed gravel were directly correlated with the percentage of stream reach that was altered. The greatest erosion and deposition resulted in reaches with a high proportion of alteration, whereas reaches with a lower proportion of alteration were less affected. Pools occurred less frequently in bulldozed than in backhoe-altered areas, although this may have been due to stream characteristics rather than the type of alteration. Shape and integrity of stream banks differed distinctly between the two types of alteration. Banks were left relatively unchanged in shape during dredging, except that in some places they were nearly covered with material removed from the streambed. Some of the riparian vegetation survived. Stream banks and riparian vegetation in bulldozed areas were eliminated, as banks were either tapered back or completely covered, with no deep water left in close proximity. In all bulldozed sites the trout populations were not self-sustaining, either because of few spawning adults or little recruitment and survival of age 0 trout. No long-term differences in growth rates were observed for trout in altered or unaltered reaches. During the study, dredging had less affect than bulldozing on survival of age 0 fish, but there were indications that dredging would reduce spawning in the future.

High stream flows in spring appeared to be required to maintain the depth and frequency of pools. Normal spring flows through altered reaches removed streambed materials deposited in pools by the alteration process, restoring them to near pre-alteration depths. Although the location of pools may have been changed somewhat as a result of channelization and subsequent restoration by fluvial processes, the number of pools was essentially the same. Low spring flows did not restore many altered pools and left some pools in unaltered areas shallower than usual. Although about equal amounts of erosion occurred during the low flows of all and the high flows of spring in altered stream reaches, most deposition occurred during the high flows in spring.

During low stream flows, brown trout and whitefish used deep pools. Because such pools were absent from severely channeled areas, fish moved from these altered areas into areas that contained pools but returned when stream flows were normal. Although the biomass and production of brown trout were adversely affected by stream channel alterations, these measurements failed to show that trout from severely channeled areas depend on more natural reaches for survival during low stream flows and for recruitment of young.

Production of brown trout and mountain whitefish was directly related to the proportion of a reach in pools, being highest in the reach with the most pools and least in the reach with the fewest. Biomass followed this same trend.

Growth of whitefish was faster in both altered and unaltered areas of the Blacksmith Fork and Logan rivers than has been reported in the literature for most other locations. Production was greater than previously found for a reach that was the lower limit of their occurrence in the Logan River.

Trout and whitefish population estimates, biomass, and production over a year's time fluctuated widely in both natural and altered sites, indicating the necessity to measure these parameters seasonally to adequately describe the ecology of the population.

Mean annual densities and standing crops of invertebrates showed no significant differences between sites, reflecting the heterogeneity of the stream habitat and its resultant sampling variability, as well as seasonal changes and the relatively short-term effects of alterations on these parameters.

Shannon diversity indices for invertebrates increased slightly immediately following stream channel alterations but decreased as recolonization began by the more mobile families, such as Chironomids, Simuliids, and Baetids.

All of the stream channel perturbations had the same type of effect on the macroinvertebrates--lowered standing crops (numbers and weight), slightly lower Shannon diversity index, and an adverse effect on production.

The duration of the impact by the perturbation on the benthic community was largely dependent upon the rate of return of substrate stability.

Irrigation diversions coupled with stream channel alterations produced a greater detrimental effect on fish and macroinvertebrates than occurred from either of these laterations along. (Authors' summary/conclusions)

Activity: channelizing waterways; water regulation/withdrawal/irrigation.

Impact: change in depth or velocity of water; addition of substrate materials; physical disturbance of substrate materials; alteration of natural cover - riparian vegetation; introduction or removal of species.

Yearke, L.W. 1971. River erosion due to channel relocation. Am. Soc. Civil Eng., Civil Eng. 41:39-40. (ADF&G, Habitat Library, #R5115.)

Channel relocation work is a phase of hydraulics little known by highway engineers. A channel change in New Hampshire's Peabody River was studied from 1961 through 1968. The river was shortened by approximately 850 ft, and its alignment was straightened. Immediately postconstruction, the channel began to seek its hydraulic gradient through erosion and scour. The major adjustment took place in the first year, with decreasing adjustments of each year thereafter. The original channel had an average fall of 52 ft/mi, and the relocated channel was steepened to 80 ft/mi 7 yr postconstruction and underwent aggradation. Scour within the channelized section resulted in localized bed adjustments of up to 18 ft, and in some places the stream width increased three to four times its original width due to severe erosion. The effects of these alterations on biota were not studied.

Activity: channelizing waterways.

Impact: change in depth or velocity of water; addition of substrate materials.

Yee, C.S., and T.D. Roelofs. 1980. Planning forest roads to protect salmonid habitat. U.S.D.A. Forest Service, Gen. Tech. Rept., PNW-109, 26 pp. Report no. 4, in, W.R. Meehan (ed.), Influence of forest and rangeland management on anadromous fish habitat in western North America. Pac. NW For. and Range Exper. Sta., Portland, OR. (ADF&G, Habitat Library, #B2439.)

This report describes how elements of a forest transportation system cause environmental changes that affect anadromous fish habitat and provides guidelines for the design, construction, and maintenance of these facilities to minimize adverse effects. Major effects discussed are increased sedimentation from transportation networks, the hindrance to fish migration of drainage structures, and possible changes in water quality from road stabilization additives.

Activity: grading/plowing.

Impact: change in turbidity or suspended sediments; addition of substrate materials; physical disturbance of substrate materials; addition of physical barriers - partial obstructions.

Young, D.R., G.V. Alexander, and D. McDermott-Ehrlich. 1979. Vessel-related contamination of southern California harbours by copper and other metals. Mar. Pollut. Bull. 10(2): 50-56. (ADF&G, Habitat Library, #R3879.)

A number of trace contaminants (mercury, tin, chromium, lead, zinc, cadmium, and polychlorinated biphenyls) appear to be introduced to nearshore marine waters as a result of vessel-related activities. The authors conducted a study of the application of antifouling paints to boats in twelve marinas and harbours along the southern California coast. Copper concentrations were determined in samples of the principal brands of paints used. To determine the degree to which the biota can be contaminated by vessel-related activities in nearshore waters, the authors measured the concentrations of trace metals in tissues of the bay mussel Mytilus edulis. Mussel samples were collected from intertidal areas of San Pedro, San Diego, and Newport harbours. Comparative studies using this bioindicator suggest that harbour-related activities can be as important a source as coastal wastewater discharges in the contamination of nearshore marine ecosystems.

Results indicated that about 5% of the recreational boats in southern California marinas are painted once a year and that, on the average, approximately one U.S. gallon (3.8 l) of paint is used per boat. Estimated quantities of antifouling paint applied to recreational boats in 1973 in 12 major marinas of southern California was 295,600 l/yr. The corresponding estimated application rate of copper via this mode (180 metric ton/yr) is more than one-third the annual emission rate from major municipal wastewaters (510 metric ton/yr), and twice the estimated input from surface runoff and dry aerial deposition (approximately 70 metric ton/yr). Results of trace element studies on M. edulis reflected this copper input in marina and nearshore coastal areas. Levels of copper in digestive gland, gonadal, adductor muscle and remaining tissues were up to ten times the natural levels. In addition, the vessel-related materials cadmium, chromium, lead, tin, zinc, and PCB were measured at levels 2 to 20 times above background in one or more tissues of specimens collected from certain areas of high vessel activity. Corresponding contaminations by these constituents (as well as silver and nickel, but excepting zinc) occurred in coastal specimens collected near the Los Angeles County submarine discharge of municipal wastewater. The authors concluded that both vessel-related activities and coastal wastewater discharges can lead to distinct elevations of such trace pollutants in nearshore marine organisms. (Author's summary: modified).

Activity: human disturbance; transport personnel/equipment/material - water.

Impact: change in levels of heavy metals.

Zimmer, D.W., and R.W. Bachmann. 1976. A study of the effect of stream channelization and bark stabilization on warmwater sport fish in Iowa: Subproject No. 4. The effects of long-reach channelization on habitat and invertebrate drift in some Iowa streams. Iowa Cooperative Fishery Research Unit, Iowa State Univ. USFWS, Office of Biological Services, FWS/OBS-76-14. (ADF&G, Habitat Library, #B0995.)

Relationships between channel morphometry, habitat diversity, and invertebrate drift density were studied in 11 natural and channelized stream segments of the upper Des Moines River Basin during 1974 and 1975. Gradients of the study sites ranged from 0.17 to 2.18 m/km sinuosity index values were between 0.95 and 1.67. Sinuosity was defined as the ratio of channel length to downvalley distance and index values were calculated as the ratio of the distance measured along the stream channel to the distance measured along the valley axis.

The most obvious effect of channelization on stream habitat was a reduction in the diversity of water depth and current velovity. There was a significant positive correlation between channel sinuosity and the variability of stream depth and velocity. Invertebrate drift density, expressed as biomass and total counts, was also correlated with channel sinuosity. Sinuous streams had greater concentrations of drifting organisms than did straight channels. There was no relationship between drift density and channel gradient. The impact of channelization on habitat diversity and invertebrate drift density might be minimized if channels were designed with greater sinuosity index values. (Author's abstract: modified)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; alteration of natural cover - overhanging bank or shoreline.

Zimmer, D.W., and R.W. Bachmann. 1978. Channelization and invertebrate drift in some Iowa streams. Water Res. Bull. 14(4):868-883. (ADF&G, Habitat Library, #R5116.)

Relationships between channel morphometry, habitat diversity, and invertebrate drift density were studied in 11 natural and channelized stream segments of the upper Des Moines River basin during 1974 and 1975. Gradients of the study sites ranged from 0.17 to 2.18 m/km; sinuosity index values were between 0.95 and 1.67. The most obvious effect of channelization on stream habitat was a reduction in the diversity of water depth and current velocity. There was a significant (P=0.05) positive correlation between channel sinuosity and the variability of stream depth and velocity. Invertebrate drift density, expressed as biomass and total counts, was also correlated with channel sinuosity. Sinuous steams had greater concentrations of drifting organisms than did straight channels. There was no relationship between drift density and channel gradient. The impact of channelization on habitat diversity and invertebrate drift density might be minimized if channels were designed with greater sinuosity index values. (Annotation from USFWS 1980)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; alteration of natural cover - overhanging bank or shoreline.

Zimmerman, R.C., J.C. Goodlett, and G.H. Comer. 1967. The influence of vegetation on channel form of small streams. Pages 255-275 in Symposium on river morphology. Reports and discussions. Publ. No. 75. International Association of Scientific Hydrology, General Assembly of Bern, 25 September-7 October 1967. L'Association Internationale d'Hydrologie Scientifique, Braamstraat 61, Gentbrugge, Belgique (Belgium). (ADF&G, Habitat Library, #R2540.)

Data on channel width of several small streams in the Sleepers River basin of northern Vermont have provided some measure of the influence of vegetation on channel form. Along five streams, for which there are complete records of variation in channel width, width does not increase in a downstream direction as far as points with drainage areas of 0.2 to 0.8 mi^2, presumably as a result of disturbance and encoachment by vegetation. In one basin with an area of 0.8 mi^2 channel width is clearly related to type of vegetation, as the channel is alternately wide under forest and narrow in sod. Along one stream, width increases in discharge where the drainage area exceeds 0.3 mi^2, but the variability in width (expressed as the standard deviation from mean and as a coefficient of relative variability) also increases, reaching a maximum where the drainage area is about 2 mi^2. Relatively uniform channel widths occur, on the other hand, where the drainage area is about 6 mi^2. Similar relationships were found in other streams sampled. In one stream, however, the mean channel width under forest where the drainage area is about 1.3 mi^2 exceeds by more than 5 ft the mean width of the same stream where the drainage area is 2.8 mi^2 and the vegetation along the stream is predominantly sod.

In the Sleepers River basin, there are apparently two thresholds along streams. In a downstream direction, the first threshold occurs at points with drainage areas of 0.2 to 0.8 mi^2. Upstream from these points, width does not increase in a downstream direction, living tree roots cross the channel, and dams of organic debris are common. The flow is commonly underground. Points with drainage areas of 0.2-0.8 mi^2 have annual high flows of 10 to 20 cfs. With drainage areas exceeding 0.2-0.8 mi^2 widths increase, but channel form is highly variable, and mean widths may vary by as much as 5 ft depending upon the type of vegetation. Relatively uniform widths occur, regardless of vegetation, where the drainage area exceeds 4 to 6 mi^2. Points with drainage areas of about 5 mi^2 are apparently the second threshold. These points have annual high flows in the range of 100 to 150 cfs. Beyond these points, the influence of vegetation on channel form is marginal compared with that of geologic differences and the sinuousity of the flow itself.

Vegetation influences channel form by altering the roughness and shear strength of bed and banks. In addition, non-fluvial processes such as the windthrow or frost-heaving of streambank trees may locally double or triple the channel dimensions that would occur with the same discharge regimen in the same geologic setting. (Author's abstract)

Activity: channelizing waterways.

Impact: change in depth or velocity of water; alteration of natural cover - riparian vegetation; alteration of natural cover - overhanging bank or shoreline.