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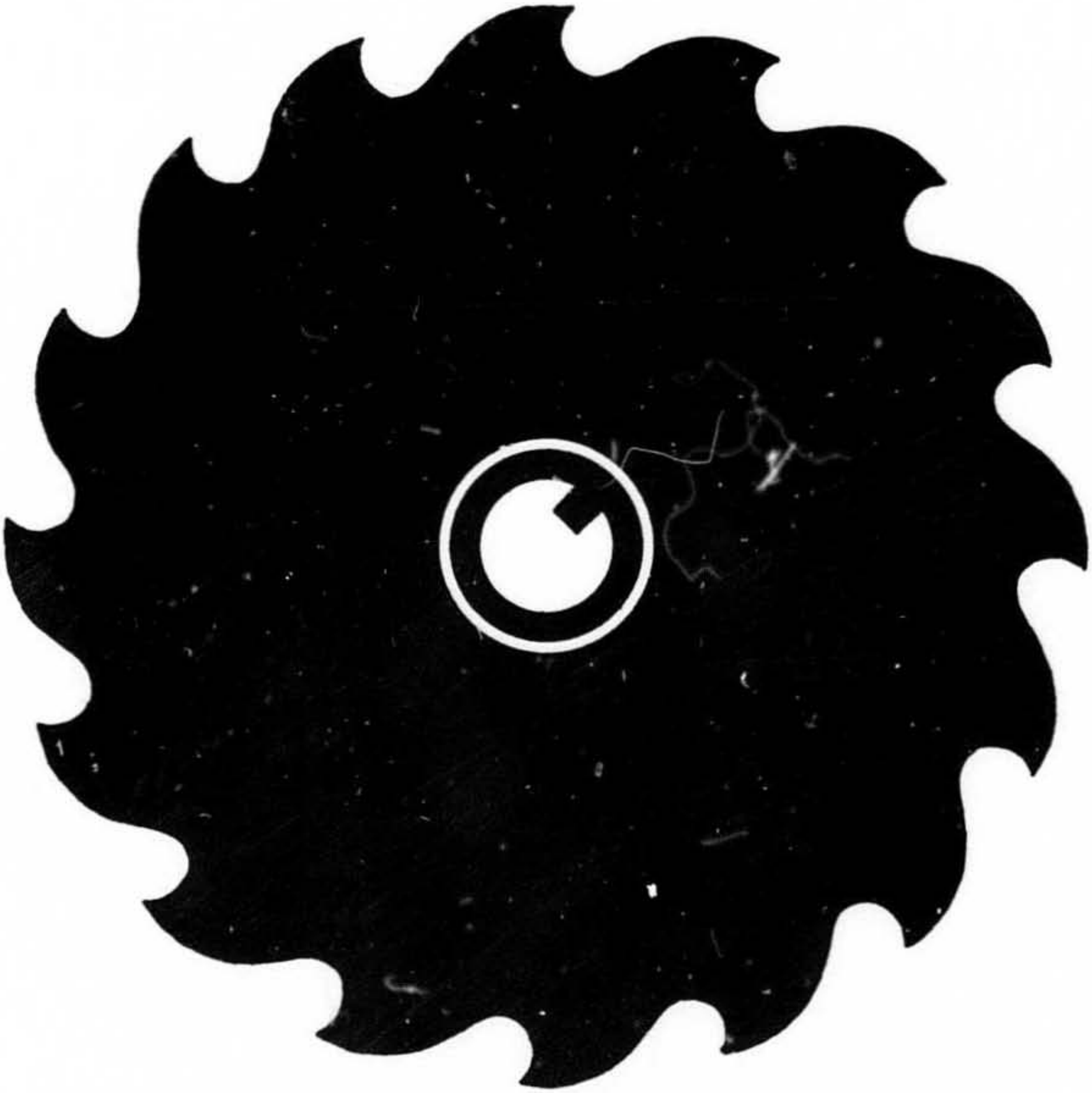
CAMPS AND MILLS



General Technical Report PNW-113
August 1980

Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America

PROCESSING MILLS AND CAMPS

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USDA FOREST SERVICE
ANADROMOUS FISH HABITAT
PROGRAM

U.S. Department of Agriculture Forest Service
Pacific Northwest Forest and Range Experiment Station

ABSTRACT

For nearly 50 years, effluents from pulp and paper mills have been known to be toxic to fish and other aquatic animals. Lethal concentrations have been determined for several species of fish and other organisms. Many factors--such as water temperature, age of fish, and additional stresses--affect the ability of fish to withstand pollution. Kraft mill wastes are generally more toxic than sulfite wastes. The high biological oxygen demand of sulfite wastes is often more serious than the chemical toxicity of the effluents. Studies on the effect of kraft effluents on invertebrates show that none of them are more sensitive than juvenile salmonids and some species are more resistant. Fish habitat may **also** be affected by mill stack emissions. High concentrations of sulfur dioxide may damage or kill trees and other vegetation. The effect of logging camps on fish habitat is largely unknown.

KEYWORDS: Pulp/paper industry, toxic effects (biocide), wood wastes, fish habitat, water quality.

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INFLUENCE OF FOREST AND RANGELAND MANAGEMENT ON ANADROMOUS FISH HABITAT IN WESTERN NORTH AMERICA

William R. Meehan, Technical Editor

11. Processing Mills and Camps

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PREFACE

This is one of a series of publications summarizing knowledge about the influences of forest and rangeland management on anadromous fish habitat in the Western United States. This paper addresses the effects of processing mills and camps on anadromous fish habitat. Our intent is to provide managers and users of the forests and rangelands of the Western United States with the most complete information available for estimating the consequences of various management alternatives.

In this series of papers, we summarize published and unpublished reports and data as well as observations of resource scientists and managers. These compilations should be valuable to resource managers in planning uses of forest and rangeland resources, and to scientists in planning future research. The extensive lists of references serve as a bibliography on forest and rangeland resources and their uses.

Previous publications in this series include:

1. "Habitat requirements of anadromous salmonids," by D. W. Reiser and T. C. Bjornn.

2. "Impacts of natural events," by Douglas N. Swanston.

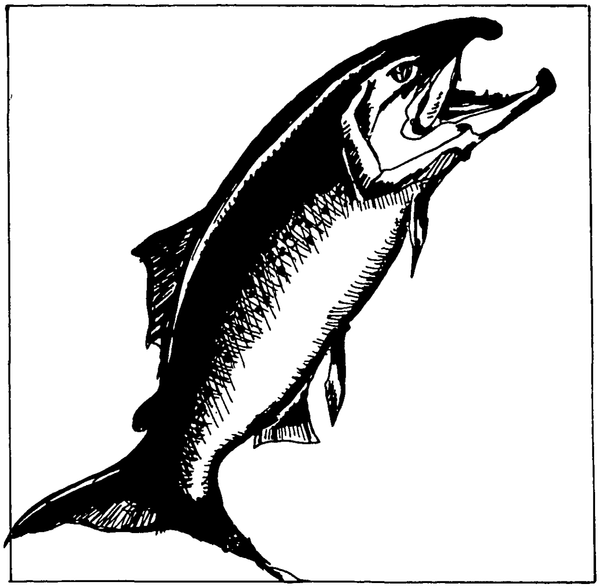
4. "Planning forest roads to protect salmonid habitat," by Carlton S. Yee and Terry D. Roelofs.

TABLE OF CONTENTS

COMMON AND SCIENTIFIC NAMES OF TROUTS, FAMILY SALMONIDAE[1/]

Common name	Scientific name
Pink salmon	*Oncorhynchus gorbuscha* (Walbaum)
Chum salmon	*Oncorhynchus keta* (Walbaum)
Coho salmon	*Oncorhynchus kisutch* (Walbaum)
Sockeye salmon (kokanee)	*Oncorhynchus nerka* (Walbaum)
Chinook salmon	*Oncorhynchus tshawytscha* (Walbaum)
Cutthroat trout	*Salmo clarki* Richardson
Rainbow (steelhead) trout	*Salmo gairdneri* Richardson
Atlantic salmon	*Salmo salar* Linnaeus
Brown trout	*Salmo trutta* Linnaeus
Arctic char	*Salvelinus alpinus* (Linnaeus)
Brook trout	*Salvelinus fontinalis* (Mitchill)
Dolly Varden	*Salvelinus malma* (Walbaum)
Lake trout	*Salvelinus namaycush* (Walbaum)

1/ From "A List of Common and Scientific Names of Fishes from the United States and Canada," American Fisheries Society Special Publication No. 6, Third Edition, 1970, 150 p.



INTRODUCTION

Many pulp and paper mills in North America are either on or near tidal estuaries or on rivers adjacent to estuaries. The anadromous fish that migrate through these estuaries and rivers are valuable for commercial and sport fishing. Inevitably some of these fish contact mill effluents at some concentration.

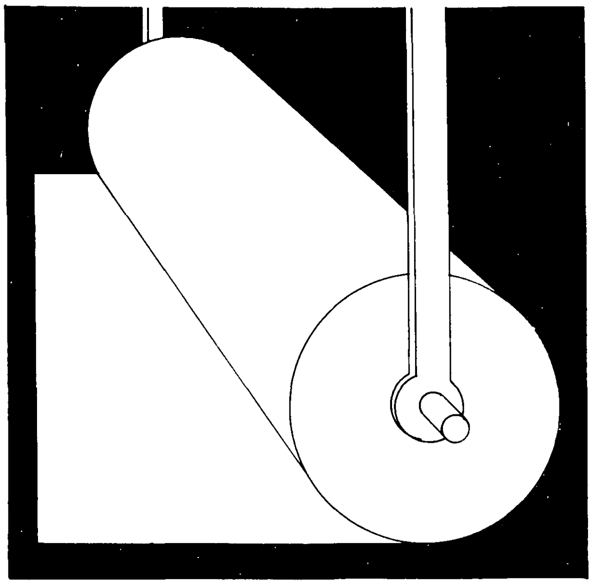
For nearly 50 years, we have known that effluents from pulp and paper mills may be toxic to fish and other aquatic animals. Effluents from both kraft and sulfite mills are complex mixtures that differ greatly in toxicity, depending on many factors. The toxicity of mill effluents results from the combined activity of a number of chemicals, some of which have not been completely identified. In addition to acute toxicity, pulp and paper mill effluents may be harmful to fish and other aquatic animals because of their biological oxygen demand. High concentrations of wood sugars in mill wastes require oxygen during decomposition; hence, as the sugars are stabilized, dissolved oxygen in the receiving water is rapidly depleted. Dissolved oxygen is required by all aquatic animals except anaerobic bacteria.

The difficulty of separating effects of chemical toxicity from effects of biological oxygen demand, and the inability to identify the chemical constituents of effluents, have complicated pollution evaluation studies in the past. The recent development and testing of reproducible bioassay procedures has dramatically changed this situation. Simple, accurate, and sensitive biological assessments are now possible (Walden 1976).

The acute toxicity of various pulp and paper mill effluents is often quite low, Despite their low toxicity, pulp and paper discharges may have a high impact on receiving waters because of the tremendous volumes discharged.

Considerable technological progress in the past decade has reduced harmful effluents. Modern mills that meet Federal and State requirements for pollution abatement differ substantially from the mills that operated 20 or 30 years ago.

Many of the logging camps in Alaska and British Columbia are closely associated with pulp and paper mills because much of the harvested timber goes to the mills. Because of this close association, a discussion of camps and their potential effects on anadromous fish habitat is included in this paper.



PROCESSING MILLS

TOXICITY OF EFFLUENTS

The toxicity of effluents from pulp and paper mills has been studied for many years. Some of this work was on the effects of pulp effluents on salmonid fishes (Dimick and Haydu 1952, Lasater 1953, Williams et al. 1953, Alderdice and Brett 1957, Van Horn 1958, Waldichuk 1960, Howard and Walden 1965, Servizi et al. 1968).

A general review of the environmental effects of pulp and paper wastes has been prepared by Marier (1973). Van Horn (1961, 1971) reviewed the pulp and paper industry as it affects aquatic biology. Walden (1976) published an excellent review on the toxicity of effluents from pulp and paper mills.

Effluents from both kraft and sulfite mills are complex mixtures that differ greatly in toxicity depending on many factors. Because all chemical constituents have not been identified, the effects must be assessed biologically. Several species of fish and many other aquatic organisms have been used for test purposes (Dimick and Haydu 1952, Lasater 1953). Laboratory bioassays have been used to predict toxicity under conditions in natural ecosystems. The definition of reproducible bioassay procedures has been an important step in making bioassays useful (Walden 1976). Simple, accurate, and sensitive bioassays are now possible. Data are converted into toxic units, which may be compared directly, even though bioassay procedures may vary. Maximum accuracy is achieved with 50 percent fish survival. Most toxicity tests require at least 24 hours' exposure time (Walden 1976).

For pulpmill effluents, chemical assays are not feasible. Some toxicants have not yet been identified; consequently, they cannot be assayed chemically. Chemical assays would only be useful if they could be correlated with biological responses.

Because of the low concentration of toxicants in effluents from pulp and paper mills, large amounts of effluent must be used in solutions to be bioassayed. The high biological oxygen demand of these solutions requires oxygenation to maintain fish respiration during the tests (Walden 1976).

EFFLUENTS OF KRAFT MILLS

Reported toxicity of kraft wastes to fish dates back to the work of Ebeling (1931) in Sweden. Many workers since then have confirmed that concentrations of kraft mill effluents needed to kill fish ranged from 10 to 100 percent.

The first studies with salmonids (Dimick and Haydu 1952) demonstrated that sodium hydroxide, methyl mercaptan, sodium sulfide, and hydrogen sulfide were toxic (table 1).

Seven pulpmills were monitored daily for 40 days to determine the amount and duration of effluent toxicity. All sewers in the kraft mills contained toxic chemicals, and substantial daily variation in toxicity was common. Toxicity levels of effluents seldom remained constant more than 12 hours and often varied more frequently (Howard and Walden 1971).

Howard and Walden (1965) studied the toxicity of streams with kraft-process effluents to guppies, Poecilia reticulata (Peters), and sockeye salmon in fresh water at neutral pH. As much as 75 percent of the mortality reported by previous authors was caused by an imbalance in pH. Fish acclimated to increasing concentrations of effluents in a few days. Test fish exposed to gradually increasing effluent could survive concentrations considerably higher than the values demonstrated as lethal in the bioassays. Thus, concentration values related to various rates of mortality, such as LC_{50} (50 percent of the test animals are killed), can be misleading. Length of exposure, other stresses on the fish, pH and temperature of the water, age of the fish, and many other factors can significantly affect pollution concentrations necessary to cause fish mortality.

Effects of kraft effluents on invertebrates indicate that none are more sensitive than juvenile salmonids and some species are much more resistant (Walden 1976).

SULFITE WASTES

Williams et al. (1953) first demonstrated that sulfite waste liquids were acutely toxic to fish. Previous workers had difficulty demonstrating toxicity, other than the effects of heavy oxygen demand. Kondo et al. (1973), working with neutral sulfite semichemical wastes, showed that they were about one-third as toxic as kraft wastes. Toxicity did not diminish in storage as it did with kraft

Table 1--Threshold concentrations (mg/l) of toxicants in kraft mill wastes lethal to salmonid fishes (after Dimick and Haydu 1952)

Chemical	Chinook salmon	Coho salmon	Cutthroat trout
Hydrogen sulfide	0.3	0.7	0.5
Methyl mercaptan	.5	.7	.9
Sodium sulfide	1.8	1.3	1.0
Sodium hydroxide	27	11	10
Sodium carbonate	58	44	33
Sodium sulfate	--	10,000	2,500

wastes. Holland et al. (1960) found no significant difference in toxicity in ammonia-base and calcium-base pulping liquors.

The toxicity to fish of sulfite pulping wastes is well documented, although the difficulty in segregating toxic effects from those of oxygen demand indicates the limited role toxicity alone plays in natural ecosystems (Walden 1976).

Literature on the effects of sulfite wastes on organisms other than fish is scarce. The available evidence shows that bivalves are especially susceptible. Odlaug (1949) showed that concentrations as low as 100 parts per million of spent sulfite liquor reduced the pumping rate of Olympia oysters (_Ostrea lurida_ Carpenter) by 8 percent after immediate exposure. Complete cessation of pumping occurred after 15 days. Stein et al. (1959) showed that concentrations of ammonia-base, spent sulfite liquor greater than 55 parts per million affected spawning of oysters, but lower concentrations stimulated activity. Oysters appear to be more sensitive to spent sulfite wastes than any other species tested (Woelke 1967).

SUBLETHAL EFFECTS OF PULPMILL EFFLUENTS

Biologists have long recognized that concentrations approaching lethal amounts of pollutants, as determined in bioassays, are not safe for survival and maintenance of fish stocks. (Fry 1971). The results of bioassays are valueless and misleading unless they can be related to concentrations producing no harmful effects to the ecosystem. Stresses are cumulative, and any stress on an organism reduces its ability to withstand other stresses.

The known sublethal effects of pulp and paper effluents are attributable to coniferous fibers, hydrogen sulfide, and nonvolatile soluble toxic substances (Walden 1976). The last group is of major environmental concern.

Walden and Howard (1968) described effects displayed by fish after exposure to lethal concentrations of kraft effluent: loss of schooling, respiratory distress, abnormal gill movements, reluctance to eat, loss of equilibrium, convulsive coughing, excessive mucous production, and finally death.

Jones et al. (1956) showed that some species of salmon avoided regions containing pulpmill waste. Chinook salmon were best able to avoid the waste, coho salmon were less able, and steelhead trout showed no noticeable reaction. Inconsistent results were demonstrated in some other studies, such as those of Dimick et al.

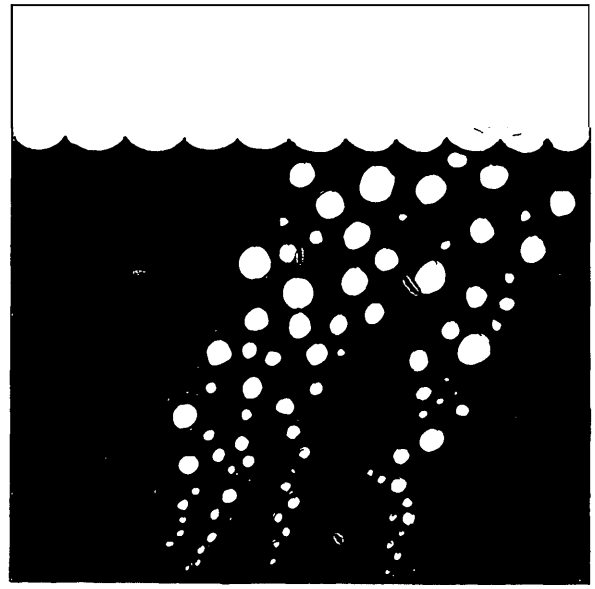
(1957); salmon sometimes avoided concentrations that attracted other test fish.

The ability of fish to swim is affected by pulpmill wastes (Howard 1973, 1975). Howard and Walden (1974) developed techniques to measure swimming; speed and stamina decreased after effluents reached a threshold concentration.

Fish growth may be adversely affected 'by moderate to high concentrations of kraft mill effluents, but low concentrations stimulated growth (Webb and Brett 1972).

Schaumburg et al. (1967) studied the effects of sublethal concentrations of kraft effluent on fish respiration. They found that stressed fish reversed the flow of water past their gills; this was designated as "coughing." Coughing increased with increasing concentrations of effluents.

Evidence of effects of sublethal concentrations of wastes from pulp and paper mills on organisms other than fish is not extensive. Available data indicate that the threshold at which sublethal concentrations affect invertebrates corresponds roughly to that affecting fish (Walden 1976).



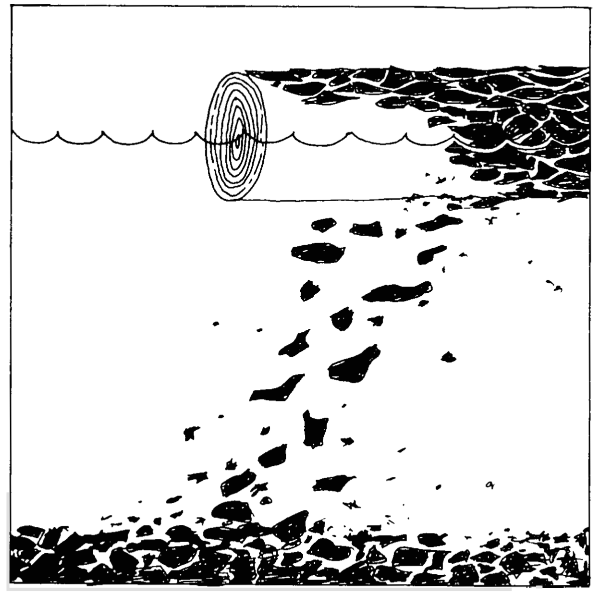
OXYGEN DEMAND

High concentrations of wood sugars in sulfite wastes require oxygen during decomposition. The oxygen requirements for stabilization of the sugars result in a high biological oxygen demand which can result in rapid depletion of dissolved oxygen in the receiving water (Waldichuk 1960).

Kraft mill wastes also contain high concentrations of organic material, but not nearly as much as in sulfite liquor.

Walden (1976) stated that difficulties in segregating toxic effects from those caused by oxygen demand emphasize the limited role toxicity plays in natural situations, compared to problems arising from potential oxygen depletion. Thus, the primary effect of sulfite wastes is apparently to increase biological oxygen demand.

The dissolved oxygen level required to sustain fish varies considerably, because it depends on other factors such as water temperature, salinity, pH, fish species, and other stresses on the fish. Despite efforts to decrease the biological oxygen demand of wastes from pulp and paper mills, the effect of these wastes on dissolved oxygen remains a problem in some receiving waters.



SUSPENDED SETTLEABLE MATERIALS

Bark, chips, and pulp fibers concern fishery biologists and others because they have long-term effects on the aquatic environment. As these materials begin to cover the bottom, the rich fauna often found there is either destroyed or forced to move. Fish that normally feed on or near the bottom also find the area unattractive and move elsewhere. As the organic materials start to decompose and dissolved oxygen in the water is used up, hydrogen sulfide is released. The bottom layer of water, with low dissolved-oxygen levels, may become very thick and, thus, unsuitable for many species of food fish. This is especially true in inlets and other restricted locations where strong tidal flushing does not occur.

Particles of bark, chips, and fibers come mainly from drum and hydraulic barkers, paper machines, and from transferring chips from scows to the mill. Bark also sloughs off logs during raft transport and during storage in holding ponds. Log-transfer sites often contain heavy accumulations of bark and other wood debris (Schaumburg 1973).

Row and Cook (1971) found that most of the toxicity from mechanical pulping effluents was caused by resin acid soaps. Wilson (1975) studied the toxicity of effluents from newsprint operations. Biotreated effluent had no adverse reaction on any of the zooplankton and invertebrates tested.

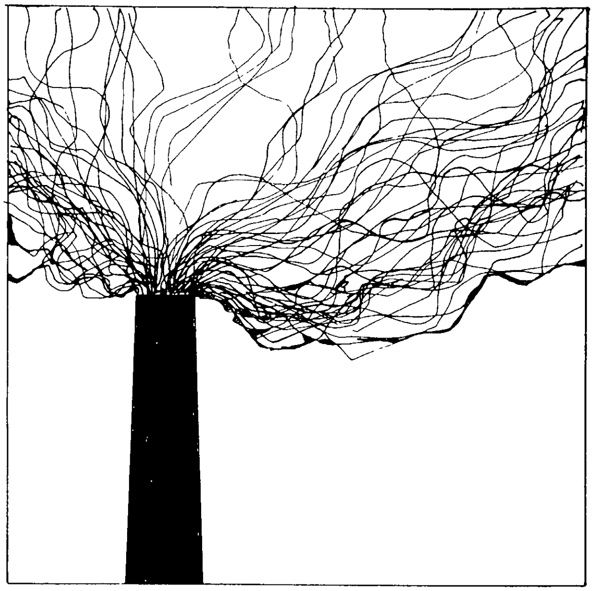
Raw wood is about half cellulose fibers. Modern mills use settling tanks, filters, and other devices to keep fibers out of receiving waters.

Bark accumulations may contaminate salmon spawning grounds (Servizi et al. 1968). Servizi and his coworkers found that the oxygen demand of bark is great enough and of long enough duration that eggs can be killed. Fine bark particles can also clog the gravel, causing egg mortality. These authors estimated that bark concentrations of 4 percent and more were likely to increase egg-to-fry mortality because of oxygen depletion at incubation velocities of 5 cm/h. Even bark concentrations of 1 percent and greater could. retard emergence. Egg mortality increased as bark accumulations increased and water flow decreased.

Even though bark leachates are toxic, studies by Schaumburg (1973) showed that leachates from logs in natural waters had little toxic effect. In a study of woodroom effluents, Howard and Leach (1973) found that softwood species tended to be more toxic than hardwood species.

Leachates from logs also contain wood sugar and other biodegradable materials that exert a large biochemical oxygen demand (Schaumburg 1973). Extracts of spruce (Picea sp.) and hemlock (Tsuga sp.) bark are also toxic to fish, shrimp (Pandalus sp.), and dungeness crab (Cancer magister Dana) (Buchanan et al. 1976). Toxic effects on salmon fry were observed as soon as 3 hours after exposure to hemlock bark extracts. After a 96-hour exposure at a concentration of 56 milligrams per liter, 50 percent of the salmon fry were killed. Spruce bark extracts were consistently toxic to all invertebrates tested.

Concentrations of leachates great enough to be toxic are unlikely except in certain locations with little or no tidal flushing, such as log-handling and storage areas.



AIR POLLUTION

Stack emissions from pulp and paper mills contain many chemicals. Some, such as sulfur dioxide (SO_2), can damage plants if concentrated sufficiently and if exposure continues long enough (Faller 1971, Linzon et al. 1972, Carlson 1974).

Sulfur dioxide is a soluble gas readily absorbed by foliage through the stomata. Absorption can also occur through wet leaf surfaces (Thomas et al. 1950). If SO_2 is not removed from the air, it oxidizes to SO_3 and becomes a sulfuric acid mist. This mist is corrosive and can cause lesions on plant tissue.

Confirmation of damage to needles by SO_2 requires that foliage samples be analyzed for sulfur. Histological examination of needles shows a distinctive syndrome unlike that caused by pathogens, drought, or freezing. Several investigators have established that high sulfur dioxide concentrations can injure or kill plants (Thomas et al. 1950, Faller 1971, Linzon et al. 1972, Ratsch 1974).

When mills are located near rivers used by salmon and other anadromous fish, they can affect fish habitat through air pollution that kills riparian vegetation. Several studies have shown the importance of streamside vegetation in reducing stream temperatures, producing logs in the stream for cover, and forming pools (Meehan et al. 1977). Trees along streambanks also harbor insects that drop into streams and are eaten by fish and other aquatic organisms.

The extent and severity of injury to riparian vegetation resulting from pulpmills depend on wind patterns and surrounding terrain as well as the amount of pollutants emitted from the mill. The presence of a pulpmill does not guarantee that nearby trees will die. If emissions are not great and air currents provide mixing, SO_2 concentrations may not be high enough to cause damage to trees or other plants (Ratsch 1974).

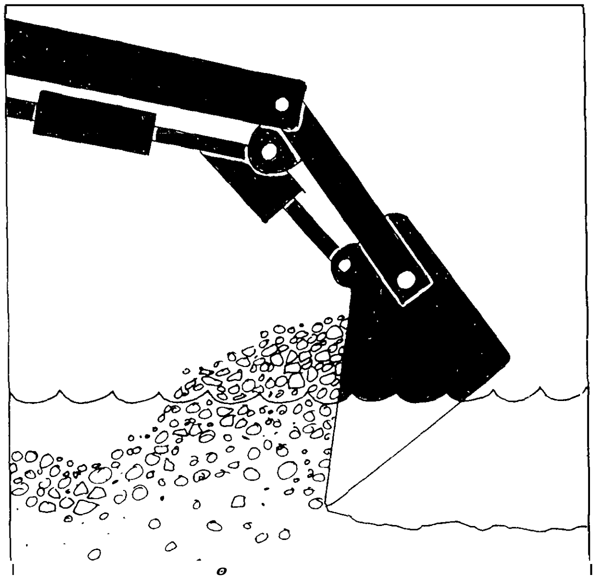
CAMPS

Except in Alaska and British Columbia, logging camps are nearly nonexistent in North America. A few camps occur in other places, but they are usually not permanent.

About 60 logging companies operate in southeast Alaska (Pease 1974). Some have floating camps that are towed from one anchorage to another but most are land based. They range in size from a one-family operation to a community of 500 people or more. Camps are usually located in protected harbors that serve as log-storage and transfer sites.

In the past, few regulations controlled logging camps. Some activities could have affected anadromous fish, but we have no record of it. Logging camps are now regulated by the Environmental Protection Agency, the USDA Forest Service, and the States. In Alaska, the State Department of Environmental Conservation also has authority. Logging camp sewage or solid wastes are unlikely to affect fish habitat adversely if regulations of these agencies are complied with. The Environmental Protection Agency requires secondary sewage treatment. Chlorinated wastewater could be toxic to fish if concentrations of chlorine were high.

Logging camps used to leave rusting cables, junked machinery, bands from log bundles, spilled fuel, and other debris on or near their sites when a camp was abandoned. No studies document the effects of these materials on fish habitat, however. Present regulations require that the sites be cleaned before the camp is moved.



GRAVEL REMOVAL

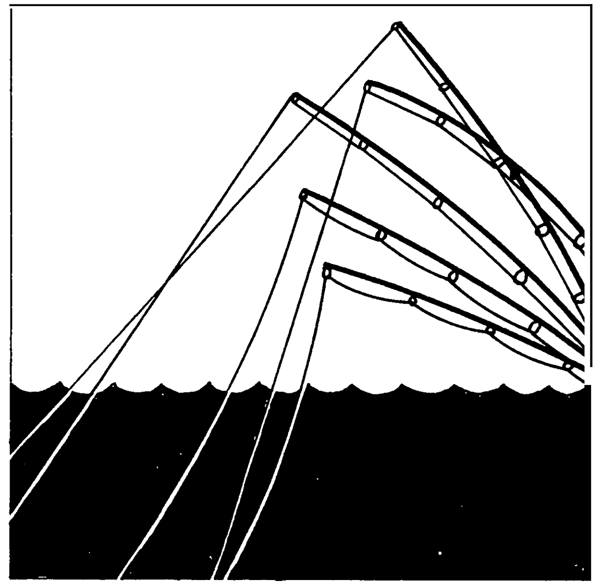
Large amounts of gravel are needed for building logging roads and developing campsites. Some locations have no source of gravel nearby, other than streambeds. Although gravel has been taken from streams in the past, this practice was probably never common and it will no doubt become less common.

Two examples of gravel removal from streambeds have been documented in Alaska. Sheridan reported on the removal of gravel from a stream on Baranof Island near Sitka, Alaska.[2] Road construction and logging were started in the Rodman Creek watershed in 1960 and completed in 1965. Surveys showed that the stream and alluvial flood plain contained the only gravel nearby; 64,000 cubic yards of gravel were taken from 16 borrow pits located on the tideflats, flood plain, and in the stream. Pink and chum salmon spawned in the intertidal area and up to 5 miles upstream. The Alaska Department of Fish and Game had records of escapement before gravel removal and continued these surveys during and after the gravel was removed. The borrow pits filled with gravel in 4 years, no significant changes were observed in streambed gradient, and the pits accelerated bank cutting in their vicinity, causing several trees to fall into the stream and a high intermittent sediment load. The pit-filling probably increased bedload movement and likely increased the instability of spawning beds upstream. Salmon escapement showed no

[2] Unpublished paper, "Effects of gravel removal on a salmon spawning stream," by W. L. Sheridan. USDA For. Serv., 26 p. On file, Forestry Sciences Laboratory, Juneau, Alaska, 1967.

decrease, even though a short-term decrease in survival of salmon embryos could have occurred because of increased sedimentation. Sheridan cautioned that gravel should be removed from streams only if no other source of gravel is available and the value of timber far exceeds the potential damage to salmon habitat.

During World War 11, large amounts of gravel were removed from four salmon streams near the Kodiak Naval Station (McVey 1959). Sections of the streambed were removed to depths of 20 feet., The fish-producing potential was reduced in two streams because the tailings from washing and screening reduced the average size of stream gravel, resulting in instability. In the other two streams, bottom materials broke up and were washed downstream. As a result, streamflow was limited to subterranean seepage during low water flows, and several miles of excellent spawning grounds became inaccessible to spawning fish. By 1958, the gravel of only one of the two streams showed signs of stabilizing.



FISHING BY RESIDENTS

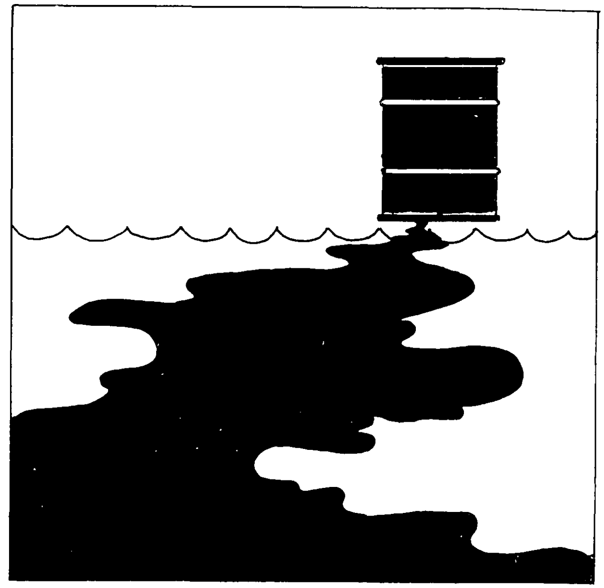
Logging camps congregate people in remote areas of southeast Alaska and British Columbia. The camps are often near highly productive stream and estuarine fisheries. This combination of people and resources results in heavy use.

Some biologists believe that logging camps are responsible for unusually heavy fishing pressure in some streams. Depletion of runs has been mentioned, but quantitative data are lacking. Species such as steelhead trout would be especially vulnerable, because the runs are small in some streams. The Alaska Department of Fish and Game has estimated that sport harvest in Rodman Creek, Baranof Island, took over 60 percent of the mature Dolly Varden char in 1963, based on tag returns. This pressure was mainly from nearby logging camps.[3/]

3/ Data on file, Forestry Sciences Laboratory, Juneau, Alaska.

The Alaska Department of Fish and Game is now conducting a statewide sport fishing survey. Information will be received from high-quality watersheds, including those near logging camps, so sport fishing harvests from logging camps can be estimated.

If anglers all carry proper licenses and observe bag limits, the logging camps only serve to distribute and congregate people, so it may be misleading to view camps as detrimental to the fisheries resource.



OTHER EFFECTS OF CAMPS

Some logging camps probably have affected the local fisheries by sewage pollution, water diversion, oil and lubricant spills, and gravel removal, although the effects of these activities have not been documented.

In light of the detailed State and Federal water and air-quality standards, logging camps are unlikely to have any appreciable effect on fish habitat now or in the future. Logging camps may be viewed as small communities, subject to the same regulations as any other community. If environmental degradation occurs it is because State and Federal regulations are being violated.

SUMMARY AND CONCLUSIONS

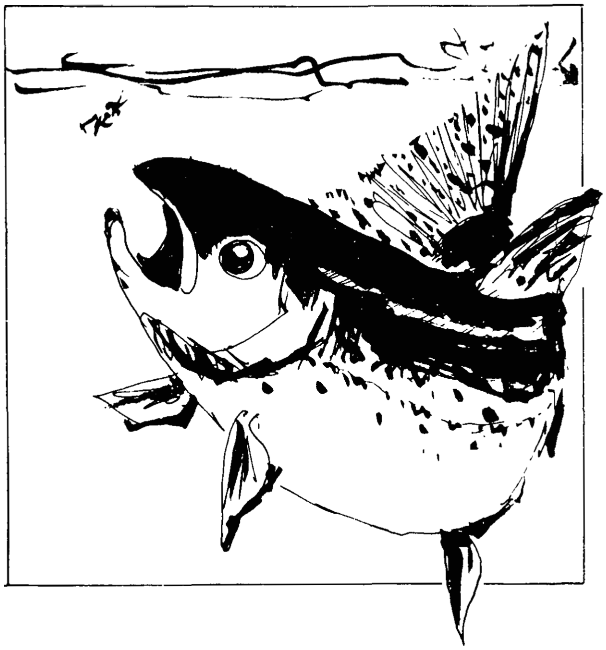
Pulp and paper mills release enormous amounts of effluents daily into receiving waters. The toxicity of these wastes varies widely and is dependent on factors such as chemical processes used, waste recovery, and biological oxygen demand caused by decomposition of sugars in the effluents.

Until recently, assessing the harmful effects of mill wastes was difficult because the chemical constituents are complex, and some remain unidentified. The relation between the concentration of many toxic constituents and biological activity has not been established. In addition, separating chemical toxicity from biological oxygen demand is often difficult. As a result chemical assays cannot be used.

Laboratory and field studies have accumulated the data needed to design accurate and sensitive acute lethal bioassays for effluents from pulp and paper mills. These bioassays have been used to identify thresholds of effluent toxicity for several aquatic animals, including salmonid fishes. This work has demonstrated that the previous history of test animals is very important. Fish and other aquatic animals can be conditioned to withstand increasing levels of pollutants to a point. Stresses tend to be cumulative, however, and such factors as water temperature and pH can compound the effects of other stresses. Despite some shortcomings, recent research on biological assessment has resulted in the development of tables showing concentrations of effluents associated with effects on various organisms. Threshold concentrations of effluents from paper mills have been based on extensive technical data; this work has been reviewed by Walden (1976).

The acute lethal bioassay is now well established for measuring toxicity of industrial pollution. Using such bioassays to determine safe levels of effluent in the environment is risky, however. Each biological system is unique; plants and animals in the system are subjected to various stresses. The amount and duration of these stresses determine the animal's ability to withstand the added stress of mill pollution. What is needed is a sublethal bioassay, sensitive enough to detect changes in the natural environment as they relate to biological requirements of the animals.

Little information is available on the effects of logging camps on anadromous fish habitat. Because camps are often near productive fish habitat, however, they are potentially hazardous. Present regulations pertaining to camps and associated activities appear adequate to prevent appreciable damage.



LITERATURE CITED

Alderdice, D. F., and J. R. Brett. 1957. Some effects of kraft mill effluent on young Pacific salmon. J. Fish. Res. Board Can. 14(5):783-795.

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. Board Can. 33(5):1188-1192.

Carlson, C. E. 1974. Sulfur damage to Douglas-fir near a pulp and paper mill in western Montana. USDA For. Serv. Rep. 74-13, 41 p. Missoula, Mont.

Dimick, R. E., and E. P. Haydu. 1952. The effects of kraft mill waste liquors and some of their components on certain salmonid fishes of the Pacific Northwest. Natl. Counc. Stream Improv., Inc., New York (Natl. Counc. Pap. Ind. Air and Stream Improv.) Tech. Bull. 51, 23 p.

Dimick, R. E., C. E. Warren, B. F. Jones, P. Doudoroff, and H. R. Amberg. 1957. Some preliminary observations on the avoidance reactions of salmonid fishes to pulp mill effluents. Natl. Counc. Stream Improv., Inc., New York (Natl. Counc. Pap. Ind. Air and Stream Improv.) Tech. Bull. 93, 14 p.

Ebeling, G. 1931. Recent results of the chemical investigation of the effect of waste waters from cellulose plants on fish. Vom Wasser 5:192-200.

Faller, N. 1971. Effects of atmospheric SO_2 on plants. The Sulfur Inst. J. 6(4):5-7.

Fry, F. E. J. 1971. The effect of environmental factors on the physiology of fish. In Fish physiology, Vol. 6, p. 1-98. W. S. Hoar and D. J. Randall (eds.). Acad. Press, New York.

Holland, G. A., J. E. Lasater, E. D. Neumann, and W. E. Eldridge. 1960. Toxic effects of organic and inorganic pollutants on young salmon and trout. Wash. Dep. Fish. Res. Bull. 5, 264 p, Olympia.

Howard, T. E. 1973. Effects of kraft pulp mill effluents on the stamina, temperature tolerance, and respiration of some salmonid fish. Ph.D. thesis, Univ. Strathclyde, Glasgow, Scotland. 183 p.

Howard, T. E. 1975. Swimming performance of juvenile coho salmon (*Oncorhynchus kisutch*) exposed to bleached kraft pulpmill effluent. J. Fish. Res. Board Can. 32(6):789-793.

Howard, T. E., and J. M. Leach. 1973. Identification and treatment of the toxic materials in woodroom effluents. Can. For. Serv. CPAR Proj. Rep. No. 148-1, 56 p. Ottawa, Ont.

Howard, T. E., and C. C. Walden. 1965. Pollution and toxicity characteristics of kraft pulp mill effluents. TAPPI 48(3):135-141.

Howard, T. E., and C. C. Walden. 1971. Effluent characteristics of bleached kraft pulp mills. Pulp and Pap. Mag. Can. 72(1):T3-T9.

Howard, T. E., and C. C. Walden. 1974. Measuring stress in fish exposed to pulp mill effluents. TAPPI 57(2):133-135.

Jones, B. F., C. E. Warren, C. E. Bond, and P. Doudoroff. 1956. Avoidance reactions of salmonid fishes to pulp mill effluents. Sewage Ind. Wastes 28(11):1403-1413.

Kondo, R., K. Sameshima, and T. Kondo. 1973. Spent semichemical pulping liquor. (3). Toxicity characteristics of SCP spent liquor and reduction of its toxicity. Japan Tech. Assoc. Pulp and Pap. Ind. 10: 476-485.

Lasater, J. E. 1953. Effects of sulfite pulp mill waste liquor on salmon food organisms. Pac. Mar. Fish. Comm., Portland, Oregon. 46 p.

Linzon, S. N., W. D. McIlveen, and P. J. Temple. 1972. Sulphur dioxide injury to vegetation in the vicinity of a sulphite pulp and paper mill. Water, Air, and Soil Pollut. 2(1973):120-134.

Marier, J. 1973. The effects of pulp and paper wastes with particular attention to fish and bioassay procedure for assessment of harmful effects. Natl. Res. Counc. Can., 13501. Environ. Secr. Publ. 73-3, Ottawa, Ont. 33 p.

McVey, R. 1959. Gravel removal and the fisheries. Alaska Fisheries Briefs. U.S. Fish and Wildl. Serv. Circ. 59, p. 14-18. Bur. Commer. Fish.

Meehan, W. R., F. J. Swanson, and J. R. Sedell. 1977. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. In Importance, preservation and management of riparian habitat: A symposium. USDA For. Serv. Gen. Tech. Rep. RM-43, p. 137-145. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Odlaug, T. O. 1949. Effects of stabilized and unstabilized waste sulfite liquor on the Olympic oyster, *Ostrea lurida*. Trans. Am. Microsc. Soc. 68(2):163-182.

Pease, B. C. 1974. Effects of log dumping and rafting on the marine environment of southeast Alaska. USDA For. Serv. Gen. Tech. Rep. PNW-22, 58 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Ratsch, H. C. 1974. Sulfur content of Douglas-fir foliage near a paper mill. U.S. Environ. Prot. Agency, EPA-660/3-74-018. 13 p. Corvallis, Oreg.

Row, R., and R. H. Cook. 1971. Resin acid soaps--toxicity and treatability. Sixth Air and Stream Improv. Conf., Tech. Sect., Can. Pulp Pap. Assoc., Quebec City. p. 87-96.

Schaumburg, F. D. 1973. The influence of log handling on water quality. U.S. Environ. Prot. Agency EPA-R2-73-085, 105 p.

Schaumburg, F. D., T. E. Howard, and C. C. Walden. 1967. A method to evaluate the effects of water pollutants on fish respiration. Water Res. 1(10):731-737.

Servizi, J. A., R. W. Gordon, and D. W. Martens. 1968. Toxicity of two chlorinated catechols, possible components of kraft pulp mill bleach waste. Int. Pac. Salmon Fish Comm. Prog. Rep. 17, 43 p. New Westminister, B.C.

Stein, J. E., R. E. Petersen, G. M. Clark, and I. E. Ellis, 1959. The spawning of Olympia oysters (Ostrea lurida) kept in spent sulfite liquor (SSL). Olympia Res. Div. Rep. Rayonnier, Shelton, Wash. 13 p.

Thomas, M. D., R. H. Hendricks, and G. R. Hill. 1950. The sulfur metabolism of plants, Effects of sulfur dioxide on vegetation. Ind. Eng. Chem. 42(11):2231-2235.

Van Horn, W. M. 1958. The effect of pulp and paper mill wastes on aquatic life. Paper presented at 5th Ont. Ind. Waste Conf., sponsored by the Water and Pollut. Advis. Comm., p. 60-66. Ont. Water Res. Comm.

Van Horn, W. M. 1961. Aquatic biology and the pulp and paper industry (Rep. No. 1). Natl. Counc. of Paper Industry for Air and Stream Improv. Inc., New York, N.Y. Stream Improvement Tech. Bull. 148, 100 p.

Van Horn, W. M. 1971. Aquatic biology and the pulp and paper industry (Rep. No. 2). Natl. Counc. of Paper Industry for Air and Stream Improv., New York, N.Y. Stream Improvement Tech. Bull. 251, 45 p.

Walden, C. C. 1976. The toxicity of pulp and paper mill effluents and corresponding measurements procedures. Water Res. 10(8):639-664.

Walden, C. C., and T. E. Howard. 1968. A cooperative research program on kraft pulp mill effluent quality. Pulp Pap. Mag. Can. 69: 67-71.

Waldichuk, M. 1960. Pulp mill pollution in British Columbia. Fish. Res. Board Can. Circ. 57, 14 p. Nanaimo, B.C.

Webb, P. W., and J. R. Brett. 1972. The *effects* of sublethal concentrations of whole bleached kraftmill effluent on the growth and food conversion efficiency of underyearling sockeye salmon. J. Fish. Res. Board Can.. 29(11):1555-1563.

Williams, R. W., E. W. Mains, W. E. Eldridge, and J. E. Lasater. 1953. Toxic effects of sulfite waste liquor on young salmon. Wash. Dep. Fish. Res. Bull. 1, 108 p. Olympia.

Wilson, M. A. 1975. Assessment of the sensitivity of major aquatic food chain organisms to newsprint mill effluents which are not acutely toxic to fish. Can. For. Serv. CPAR Proj. Rep. 328-1, 78 p. Ottawa, Can.

Woelke, C. E. 1967. Measurement of water quality with the Pacific oyster embryo bioassay. Water quality criteria, ASTM, STP 416, p. 112-120. Am. Soc. Test. Mater., Philadelphia, Pa.

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