The 1990 State/Federal Natural Resource Damage Assessment and Restoration Plan for the Exxon Valdez Oil Spill

Volume I: Assessment and Restoration Plan
Appendices A, B, C

August 1990

Dear Reviewer:

This document describes the second year of studies being undertaken to determine the injury to natural resources resulting from the Exxon Valdez oil spill. These studies are being conducted by the State of Alaska and the United States to assess related damages and develop restoration plans.

The 1990 plan has benefitted greatly from the many thoughtful public comments on the "State/Federal Natural Resources Damage Assessment Plan for the Exxon Valdez Oil Spill, August 1989." The current plan was assembled through the cooperative efforts of the State of Alaska acting through the Department of Fish and Game and the United States acting through the Federal Departments of Agriculture and the Interior, the National Oceanic and Atmospheric Administration, and the U.S. Environmental Protection Agency.

Public comment on this document will assist the Trustee Council in developing future injury assessment and restoration efforts.

Questions concerning the plan and its distribution should be directed to U.S. Department of Agriculture, Forest Service Public Affairs Office (907) 586-8806.

Comments should be received by October 15, 1990, at the following address:

Trustee Council
P. O. Box 20792
Juneau, AK 99802

We appreciate your interest and look forward to your participation in this important process.

Sincerely,

Don W. Collinsworth
Commissioner
Alaska Department of Fish and Game

Walter Stieglitz
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THE 1990 STATE/FEDERAL NATURAL RESOURCE DAMAGE ASSESSMENT AND RESTORATION PLAN FOR THE EXXON VALDEZ OIL SPILL

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INTRODUCTION

The March 24, 1989, grounding of the tanker Exxon Valdez in Alaska's Prince William Sound caused the largest oil spill in U.S. history. Approximately 11 million gallons of North Slope crude oil moved through the southwestern portion of the Sound and along the coast of the western Gulf of Alaska (see map, Fig. 1). The spill resulted in injury to fish, birds and mammals and a variety of other forms of marine life and habitats.

This plan describes the second year of the process by which damages will be assessed so that funds to restore impacted resources or the services the resources provided, can be sought from those responsible for the Exxon Valdez oil spill (EVOS). The State of Alaska acting through the Alaska Department of Fish and Game (ADF&G) and the United States acting through the federal Departments of Agriculture (DOA), Commerce (DOC), through the National Oceanic and Atmospheric Administration (NOAA), and Interior (DOI) are acting together as Natural Resource Trustees as provided by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Clean Water Act (CWA), and other state and federal authorities. The Environmental Protection Agency (EPA) is assisting in damage assessment and is coordinating the federal restoration efforts with those of the State of Alaska.

The 1990 damage assessment studies plan builds on the 1989 damage assessment studies. These studies are designed to determine the nature and extent of the injuries, loss or destruction to resources and will lead to a determination of damages. The assessment of damages for injury to natural resources requires consideration of (1) the nature of the resources at risk, (2) the nature of the oil in the aquatic environment, (3) the exposure of the resources to the oil, and (4) oil-related damages to important resources. The data provides a base for developing a restoration plan.

The purpose of determining damages--the estimated monetary value of the injured resources and the cost to restore those resources and the services they provided--is to pursue a claim against parties responsible for the spill. Funds received as the result of the claim will be used to restore, replace or acquire the equivalent of the injured natural resources and services and to reimburse agencies for relevant costs incurred. The U.S. Department of Justice and Alaska Department of Law represent the federal and state governments, respectively, in pursuits of claims.

In 1989 the Trustees developed a damage assessment plan incorporating 63 studies in ten categories. The Trustee Council monitored the assessment process to ensure that study objectives were met.

In order to identify studies that should be continued, terminated or new studies that should be initiated, the Trustee Council considered the extensive public comments on the initial plan, and consulted damage assessment investigators, other agency scientific staff, legal counsel, and independent outside expert reviewers. The studies were evaluated from five perspectives: (1) immediate injury, (2) long-term alteration of populations, (3) sublethal effects, (4) ecosystem-wide effects and (5) habitat degradation. As a result of the review, 47 of the studies were continued, 26 of the studies were discontinued or merged into other studies, and 4 new studies were initiated (Table 1). Many of the continuing studies were modified.

The studies described in this plan fall into ten categories: (1) Coastal Habitat, (2) Air/Water, (3) Fish/Shellfish, (4) Marine Mammals, (5) Terrestrial Mammals, (6) Birds, (7) Technical Services (including chemistry, histopathology, and an integrated geographic information system, complete with mapping) to support the resource studies, (8) Restoration, (9) Historic Properties and Archeological Resources, and (10) Economic Studies. The cost for the studies for the 1990 oil spill year (March 1, 1990 - February 28, 1991) is approximately $37 million.

The Coastal Habitat study measures spill-related changes in the supratidal, intertidal, and shallow subtidal zones. It is designed to document injury to resources that rely on these habitats, and to assess damages for the loss of services provided by these habitats.

The Air/Water studies determine the distribution and composition of petroleum hydrocarbons or their environmental conversion products in water, sediments, and living resources. Information gathered on the distribution and nature of the hydrocarbons and their conversion products provides a basis for documenting exposure and for determining injury to resources. The combined results of the Coastal Habitat and Air/Water studies also form a basis for estimating rates of recovery of natural resources and the potential for accelerating recovery.

The Fish/Shellfish studies focus on identifying potential injury to their various life stages in areas affected by the oil spill. Species were selected for study based on their respective niche or overall importance within the ecosystem, ability to be sampled, and the existence of an historic data base.

Marine mammal studies include direct observations of injury (e.g., through carcass counts) as well as estimates of population effects based on pathologic and toxicologic indicators (as is being undertaken with otters and seals). In addition, the direct observational data allows for inferences to be made about injuries to populations.

Terrestrial mammals near the coast may have been exposed to hydrocarbons by breathing fumes and eating oiled carcasses or vegetation. The studies will determine the presence of hydrocarbons in tissues of dead animals, and the effects, if any, of oil exposure on local populations of brown bears, Sitka black-tailed deer and river otters. Studies of reproduction in laboratory mink are also being conducted to serve as a model for assessing injury to other potentially affected species.

The plan for determining injury to birds is organized into four units: (1) surveys and censuses, (2) raptors, (3) sea birds, and (4) waterfowl, shorebirds, and passerines. The information obtained will contribute to an understanding of mortality, population changes, and other factors essential for the damage assessment process. Studies proposed for birds focus on improving the accuracy of mortality estimates and collecting data on survival and reproductive success in relation to exposure to hydrocarbons and conversion products. These and other data will be gathered on birds potentially most affected by the spill or best serving as indicators for impacts on other important ecological components.

The technical services category includes activities which provide process support or information services to all studies in the areas of analytical chemistry, quality assurance/quality control for the damage assessment process, histopathology, and an integrated geographic information system, complete with mapping.

The restoration plan describes the strategy and scope of the restoration process and feasibility studies planned for the second oil spill year. Restoration measures will be implemented as soon as it becomes ecologically feasible, appropriate methods are identified, and funds are available.

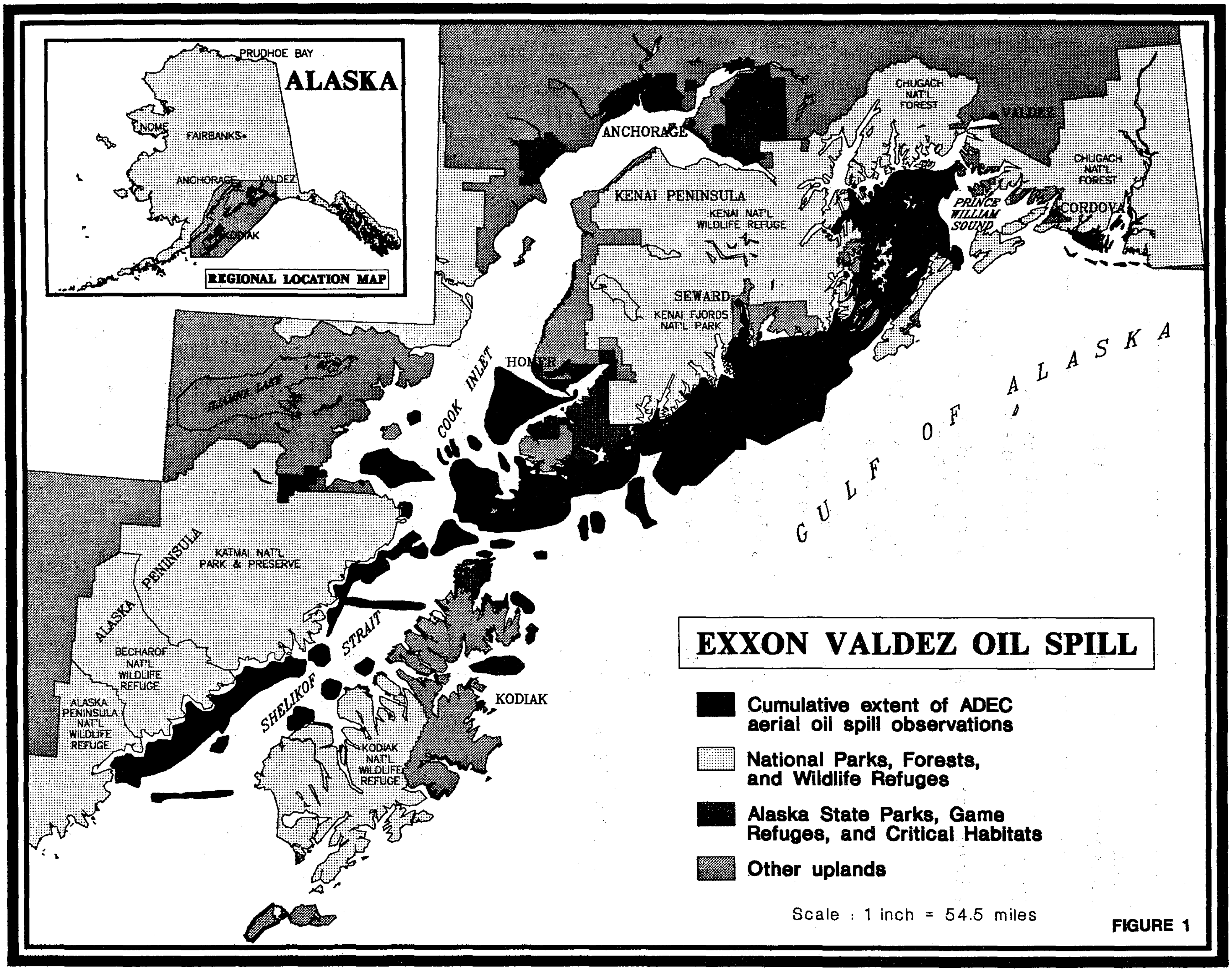
Studies on historic properties and archaeological resources will proceed in two steps: (1) inventory, description, and classification; and (2) qualitative and quantitative descriptions and measurements of changes detrimental to the archeological resources related to the spill.

The value of lost or injured natural resources, and the goods and services they provide humans, are based on results from economic studies. In this regard, damages forming the basis of the Trustees' claim against the potentially responsible parties are calculated by considering (1) the reduction of these goods and services, including intrinsic values, resulting from the spill, and (2) the cost of restoring these goods and services to their pre-spill level, replacing them or acquiring their equivalent.

The Trustees emphasized in a March 1990 letter to the Exxon Corporation and Exxon Shipping, Inc. their desire to place all state and federal injury assessment data in a public repository, providing that the two corporations do likewise. In a letter dated June 6, 1990 to the Trustees, Exxon proposed a more limited data sharing arrangement. On July 19, 1990, the Trustees and Exxon representatives discussed the creation of a public data repository. The parties agreed to establish a technical committee to seek agreement on an exchange of detailed study plans and to develop a plan based on an initial set of damage assessment studies that could be used as an example of how data would be placed in the repository.

TABLE ONE: STUDIES AUTHORIZED IN 1989 AND 1990

Study Category	Number	Title	1989	1990
Coastal Habitat	CH1	Comprehensive Assessment	X	X
Air/Water	AW1	Geographical Extent in Water	X	
	AW2	Injury to Subtidal Sediments	X	X
	AW3	Hydrocarbons in Water	X	X
	AW4	Injury to Deep Water	X	1/
	AW5	Injury to Air	X	
	AW6	Oil Toxicity		X
Fish/Shellfish	FS1	Salmon Spawning Area Injury	X	X
	FS2	Egg and Preemergent Fry Sampling	X	X
	FS3	Coded-Wire Tagging	X	X
	FS4	Early Marine Salmon Injury	X	X
	FS5	Dolly Varden Injury	X	X
	FS6	Sport Fishery Harvest & Effort	X	
	FS7	Salmon Spawning Area Injury, Outside PWS	X	X
	FS8	Egg & Preemergent Fry Sampling, Outside PWS	X	X
	FS9	Early Marine Salmon Injury, Outside PWS	X	



PRUDHOE BAY
ALASKA
NOME
FAIRBANKS
ANCHORAGE
VALDEZ
KODIAK
REGIONAL LOCATION MAP
ANCHORAGE
CHUGACH NAT'L FOREST
VALDEZ
CHUGACH NAT'L FOREST
KENAI PENINSULA
KENAI NAT'L WILDLIFE REFUGE
PRINCE WILLIAM SOUND
CORDOVA
SEWARD
KENAI FJORDS NAT'L PARK
HOMER
COOK INLET
GULF OF ALASKA
KATMAI NAT'L PARK & PRESERVE
ALASKA PENINSULA
BECHAROF NAT'L WILDLIFE REFUGE
ALASKA PENINSULA NAT'L WILDLIFE REFUGE
SHELIKOF STRAIT
KODIAK
KODIAK NAT'L WILDLIFE REFUGE
EXXON VALDEZ OIL SPILL
Cumulative extent of ADEC aerial oil spill observations
National Parks, Forests, and Wildlife Refuges
Alaska State Parks, Game Refuges, and Critical Habitats
Other uplands
Scale : 1 inch = 54.5 miles

FIGURE 1

Study Category	Number	Title	1989	1990
	FS10	Dolly Varden & Sockeye Injury, Lower Cook Inlet	X	
	FS11	Herring Injury	X	X
	FS12	Herring Injury, Outside PWS	X	
	FS13	Clam Injury	X	X
	FS14	Crab Injury	X	
	FS15	Spot Shrimp Injury	X	X
	FS16	Injury to Oysters	X	
	FS17	Rockfish Injury	X	X
	FS18	Trawl Assessment	X	X
	FS19	Larvae Fish Injury	X	
	FS20	Underwater Observations	X	
	FS21	Clam Injury, Outside PWS	X	2/
	FS22	Crab Injury, Outside PWS	X	X
	FS23	Rockfish Injury, Outside PWS	X	3/
	FS24	Trawl Assessment, Outside PWS	X	X
	FS25	Scallop Mariculture Injury	X	
	FS26	Sea Urchin Injury	X	
	FS27	Sockeye Over-Escapement		X
	FS28	Run Reconstruction		X
	FS29	Life History Modeling		4/
	FS30	Salmon Database Mgmt		X

Study Category	Number	Title	1989	1990
Marine Mammals	MM1	Humpback Whale	X	X
	MM2	Killer Whale	X	X
	MM3	Cetacean Necropsy	X	
	MM4	Sea Lion	X	X
	MM5	Harbor Seal	X	X
	MM6	Sea Otter Impact	X	X
	MM7	Sea Otter Rehabilitation	X	X
Terrestrial Mammals	TM1	Injury to Sitka Black-Tail Deer	X	X
	TM2	Injury to Black Bear	X	X
	TM3	Injury to River Otter and Mink	X	X
	TM4	Injury to Brown Bear	X	X
	TM5	Injury to Small Mammals	X	
	TM6	Reproduction of Mink	X	X
Birds	B1	Beached Bird Survey	X	X
	B2	Censuses & Seasonal Distribution	X	X
	B3	Seabird Colony Surveys	X	X
	B4	Bald Eagles	X	X
	B5	Peale's Peregrine Falcons	X	X
	B6	Marbled Murrelets	X	
	B7	Storm Petrels	X	
	B8	Black-legged Kittiwakes	X	

Study Category	Number	Title	1989	1990
	B9	Pigeon Guillemots	X	
	B10	Glaucous-winged Gulls	X	
	B11	Sea Ducks	X	X
	B12	Shorebirds	X	
	B13	Passerines	X	X
	B14	Exposure to North Slope Oil	X	
Technical Services	TS1	Hydrocarbon Analysis	X	X
	TS2	Histopathology	X	X
	TS3	Mapping	X	X
Archeology	ARCH1	Archeological Resources	5/	X
Restoration	RP1	Restoration Planning	X	X
Economics	ECON1	Commercial Fisheries Losses	X	X
	ECON2	Fishing Industry Costs	X	6/
	ECON3	Bioeconomic Models	X	6/
	ECON4	Public Land Effects	X	X
	ECON5	Recreation Damages	X	X
	ECON6	Subsistence Losses	X	X
	ECON7	Intrinsic Values	X	X
	ECON8	Research Program Effects	X	X
	ECON9	Archeological Damage Quantification	X	X

1/ AW4 Combined with AW2
2/ FS21 Combined with FS 13
3/ FS23 Combined with FS17
4/ FS29 Combined with FS28
5/ Part of Econ. 9
6/ Combined with Econ. 1

PART I

INJURY DETERMINATION/QUANTIFICATION

COASTAL HABITAT STUDY NUMBER 1

Study Title: Comprehensive Assessment of Injury to Coastal Habitats

Lead Agency: USFS

Cooperating Agencies: NOAA, DEC, NPS, FWS, ADF&G, DNR

INTRODUCTION

The purpose of the Coastal Habitat Injury Assessment is to document and quantify injuries to biological resources found in the shallow subtidal, intertidal, and supratidal zones throughout the shoreline areas affected by EVOS.

Study sites are selected and ground-truthed during Phase I. Phase II is an intensive evaluation of the study sites to determine the extent of injury to natural resources. The objective of this study is to estimate the effects of various degrees of oiling on the quantity (abundance and biomass), quality (reproductive condition and growth rate), and composition (diversity and proportion of population) of key species in the critical trophic levels of coastal communities. These data are expected to provide evidence of injury to the overall health and productivity of these critical coastal habitats, and provide information necessary to the more species-specific studies on the effects of the oil spill on affected mammals, birds and fish that use these habitats.

PHASE I

This study uses a stratified random sample design to select basic experimental units called study sites. Oiled study sites were selected from shorelines which were affected by the oil spill and control study sites were selected from shorelines which were not oiled. The shoreline was subdivided into ten strata; five habitats multiplied by two oiling types. The study sites are grouped by strata within three geographic regions: Prince William Sound (PWS), Cook Inlet/Kenai Peninsula (CIK), and Kodiak Archipelago/Alaska Peninsula (KAP). Consolidating a wide range of habitat and oiling characteristics into ten strata, coupled with the relatively coarse resolution of the available habitat and oiling data base, resulted in variances between ground-truthed classifications and mapped classifications. These variances were addressed by confining the additional, inductively selected sites in 1990 from the top 40 randomly ranked sites in PWS and the top 50 ranked sites in CIK and KAP, respectively. These sites now represent a simple random sample of the shoreline and will continue to be used to make inductive inferences to the universe of all possible sites. There are a total of 102 sites to be studied in 1990.

Sites in the very lightly and lightly oiled strata are not included for additional site selection or comprehensive sampling in 1990. This will enable the assessment to focus on moderately and heavily oiled sites and their respective controls.

Approximately 40 additional study sites will be deductively (non-randomly) selected in 1990 to provide additional spatial and habitat coverage in strata where a full array of inductive study sites could not be obtained in 1989. Approximately 18 of the additional sites will be new control sites selected to match the physical and biological characteristics of existing inductively selected oiled sites. The site selection process for control sites in 1990 will be confined to those shorelines which match, as closely as possible, the biological and physical attributes of their respective oiled sites.

In the CIK and KAP regions, additional sites (approximately 8) will be selected, where appropriate, from sites that were occupied by the National Park Service in 1989. The remaining sites will be selected using the original data base, as supplemented with September oiling classifications, aerial photos, and additional ground-truthing.

OBJECTIVES

1. To maintain a statistically valid study site selection strategy and identify additional study sites using existing map-based coastal habitat and oil impact classification schemes.

2. To ground-truth potential study sites to evaluate map-based habitat and oil impact classifications.

3. To describe and mark approximately 45 study sites in addition to the 57 sites that have been identified for comprehensive sampling in 1990.

METHODS

Four sites, representative of habitat types appropriate to each region in the original stratified random sample for the 1989 data base and ranked moderately and heavily oiled, are selected for study in 1990. Each site will be matched with a control site deductively chosen to approximate closely the physical and biological attributes of the oiled site. The selection of control sites will begin with the existing pool of randomly selected non-oiled sites that were identified and surveyed in 1989. Photographs, maps, and geomorphology and biological descriptions of the sites will be used as the bases for selection.

If a suitable control cannot be found from the existing pool of 1989 sites, candidate control sites will be identified by consulting the original data base and oiling classifications and by locating equivalent habitat types in closest proximity to the oiled sites. Approximately 5 candidate control sites will be identified for each oiled site. Sites will be visited in order of their distance from the oiled site until a suitable match is found. Sites will also be examined for any physical characteristics unique to the oiled site that have not been accounted for in the five habitat types. In PWS, control sites must be located on islands to match oiled sites that are located on islands.

Supplemental oiled sites and matched controls will be sought and added if there are fewer than three replicates of a particular habitat type in the existing sample within each region (excluding fine-textured habitats in PWS). Supplemental sites will be deductively selected to include intertidal study sites occupied by the NPS in 1989, "set-aside" (untreated) sites in PWS, and areas which provide additional spatial distribution of a particular stratum in a region. Data from supplemental sites will not be used to expand inductively estimates of injuries to the universe of potential sites. Rather, it will be used to estimate the effects of oiling and treatment on a given habitat type.

The methods for locating and marking additional study sites will follow the methods used in the 1989 reconnaissance survey.

BIBLIOGRAPHY

Alaska Department of Environmental Conservation. 1989. Oil spill impact maps. Unpublished preliminary data being developed under Air/Water Study Number 1.

Cochran, William G. 1977. Sampling techniques. Third Edition. John Wiley and Sons. New York. Chapter 11, pp. 292-324.

Environmental Systems Research Institute (ESRI). ARCINFO geographic systems software. Version 5.0. Redland, California.

Gundlach, E.R. and M.O. Hayes. 1989. Vulnerability of coastal environments to oil pollution. 12 Marine Technology Society Journal pp. 18-27.

Hayes, M.O. and C.H. Ruby. 1979. Oil spill vulnerability index maps, Kodiak Archipelago. Unpublished maps. 47 leaves.

Hayes, M.O., E.R. Gundlach, and C.D. Getter. 1980. Sensitivity ranking of energy port shorelines. Proceedings of a specialty conference on ports. American Society of Civil Engineers. New York. Pp. 697-709.

Research Planning Institute (RPI), Inc. 1983a. Sensitivity of coastal environments and wildlife to spilled oil, Prince William Sound, Alaska, and atlas of coastal resources. Prepared for National Oceanic and Atmospheric Administration. Office of Oceanography and Marine Services, Seattle, Washington. 48 leaves.

Research Planning Institute (RPI), Inc. 1983b. Sensitivity of coastal environments and wildlife to spilled oil, Shelikof Strait Region, Alaska, and atlas of coastal resources. Prepared for National Oceanic and Atmospheric Administration, Office of Oceanography and Marine Services, Seattle, Washington. 43 leaves.

Research Planning Institute (RPI), Inc. 1985. Sensitivity of coastal environments and wildlife to spilled oil, Cook Inlet/Kenai Peninsula, Alaska, and atlas of coastal resources. Prepared for National Oceanic and Atmospheric Administration, Office of Oceanography and Marine Assessment, Seattle, Washington. 64 leaves.

Research Planning Institute (RPI), Inc. 1986. Sensitivity of coastal environments and wildlife to spilled oil, Southern Alaska Peninsula, an atlas of coastal resources. Prepared for National Oceanic and Atmospheric Administration, National Ocean Service, Alaska Office and U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region. 69 leaves.

BUDGET: ADF&G

Salaries	$ 14.7
Travel	3.0
Contracts	131.5
Equipment & Supplies	7.5
Total	$ 156.7

PHASE II

PART A: Injury Determination

Coastal habitats are unique areas of high productivity supporting a diverse array of organisms, including many commercially and ecologically important species. These habitats are particularly vulnerable to oil spill impacts because of the grounding of oil in the intertidal zone, the persistence of oil in intertidal and subtidal sediments, and the effects of associated clean-up activities.

Oil may affect coastal organisms directly by coating or ingestion, with toxic effects leading to death or reproductive failure. Indirectly, oiling may cause decreased productivity, accumulation of toxic effects through the food chain, and loss of microhabitat such as algae beds. Assessment of injuries to coastal habitat resources and determination of rates of recovery require consideration of the various coastal geomorphologic types, the degree of oiling, the affected habitat, and their trophic interactions. Coastal habitats consist of three interactive zones (supra-, inter-, and subtidal). Animals may use multiple zones, necessitating a coordinated study of the effects of oiling over the entire habitat. The complexity of this system requires expertise in many disciplines. Therefore, an interdisciplinary team with the appropriate expertise, including plant and systems ecology, marine biology, and statistical analysis, has been established.

Initial field studies were completed by November 1, 1989. Processing of samples and data analysis is being conducted to determine the variance and magnitude of changes between non-oiled and moderately and heavily oiled sites.

OBJECTIVES

A. Estimate the quantity (abundance and dry weight biomass), quality (reproductive condition and growth rate), and composition (diversity and proportion of standing crop) of critical trophic levels (and subsequent impact on trophic interactions) in moderately and heavily oiled sites relative to non-oiled sites.

B. Estimate hydrocarbon concentrations in sediments and soils.

C. Establish the response of these parameters to varying degrees of oiling and subsequent clean-up procedures.

D. Extrapolate impact results to the entire spill-affected area.

E. Estimate the rate of recovery of the habitats studied and their potential for restoration.

F. Provide linkages to other studies by demonstrating the relationships between oil, trophic level impacts, and higher organisms.

METHODS

Vertical transects will be established at each of the study sites selected in Phase I. Work will be conducted along these transects in the supratidal and intertidal zones. For this study, the intertidal extends from the "0" tide mark to Mean High High Water (MHHW), and the supratidal is from MHHW or where terrestrial vegetation begins (if below MHHW) to the highest extent of possible oil occurrence. The intertidal transects will be extended into the supratidal zone at locations in the KAP where coastal plant communities occur. Primarily, this will be in fine-textured, coarse-textured, and sheltered estuarine habitats. Beach sediment texture will be determined as part of Phase I. Community composition, cover, and standing crop by trophic level will be estimated. Key species (dominant producers and food sources) will be determined and studied according to the methods listed below, to estimate the quantity, quality, and composition at each trophic level, and to collect samples for determination of hydrocarbon contamination. Sediment samples will be collected by DEC for analyses of hydrocarbon composition and changes in concentration over time. Using a geographic information approach, the impact (by habitat type and degree of oiling) over the entire area affected by the oil spill will be integrated and field-verified.

In 1990, sampling in the supratidal zone will occur in the KAP where there is extensive vegetation and sufficient wave exposure to move oil above the tide line.

Subtidal sites will be selected independent of the supra- and intertidal sites. Subtidal sites will include three physio-geographic types: bays, points and runs (straight lines). The physio-geographic areas will be further divided into three habitat types: <u>Nereocystis</u> beds, <u>Zostera</u> beds, and <u>Laminaria</u> beds. These will be further divided into strata selected according to ecological importance, potential impact, and extent of habitat within the oiled region.

Specific methods for each component of the study were developed as follows:

Coastal
1. Initial Site Survey
2. Locating Transects
3. Sample Identification and Chain of Custody

Supratidal
1. Quadrant Location
2. Determination of Plant Productivity

a. Analysis of Vegetation Nutrient Content
b. Analysis of In Vitro Digestibility
3. Analysis of Soil/Sediment Microbial Activity
4. Sampling of Soils and Sediments for Hydrocarbon Concentration

Intertidal

Invertebrates
1. Locating 1 Quadrants
2. Swath Surveys
3. Reproductive Condition
4. Growth and Survivorship
5. Hydrocarbon Sampling Procedures
6. Experimental Work
7. General Laboratory Sorting Procedures
8. Subsampling of Intertidal Samples
9. Processing of Histological Samples

Fish
1. Locating Transects
2. Locating Quadrants
3. Sampling Quadrants
4. Minnow Trap Sampling
5. Sample Storage and Identification
6. Fish for Hydrocarbon Analysis

Plants
1. Introduction
2. Study Plan
   a. Stratified Sampling
   b. Site Experiments at Selected Habitats
   c. Field Experiments

Subtidal
1. Sampling
2. Field Schedule
3. Laboratory Procedure for Benthic Invertebrates
4. Hydrocarbon Sampling Procedures
5. Data Analysis

Analysis of samples obtained in 1989 is still underway and will continue as additional samples are collected. Samples from 1990 will be processed as rapidly as possible after they are returned from the field. The data from all of the component studies are being entered into the INGRES database management system. This system is widely used, and has good data security features. Use of this data base system will therefore maximize both internal integration and availability of the data to related damage assessment projects.

BIBLIOGRAPHY

AOAC. 1980. Official Methods of Analysis of the A.O.A.C., 13th ed.
Chipperfield, P.N.J. 1953. Observations on the breeding and settlement of _Mytilus edulis_ (L.) in British waters. J. Mar. Biol. Ass. U.K. 32:449-476.

Johnson, R.D. and H.L. Bergman. 1984. Use of histopathology in aquatic toxicology: A Critique. Pp. 19-36. In _Containment Effects on Fisheries,_ V.W. Cairns, P.V. Hodson and J.O. Nriagu, eds. John Wiley and Sons.

A.L. Page, R. H. Miller, and D.R. Keeney (eds.). 1982. Methods of Soil Analysis, Part 2. _Chemical and Microbiological Properties_. Second Edition. Am. Soc. Agron.

Ropes, J.W. 1968. Reproductive cycle of the surf clam, _Spisula solidissima,_ in offshore New Jersey. Biol. Bull. 135:349-365.

Seed, R. 1969. The ecology of _Mytilus edulis_ L. (Lamellibranchiata). I. Breeding and Settlement. Oecologia. 3:277-350.

Sheehan, D.C. and B.B. Hrapchak. 1980. Theory and Practice of Histotechnology. 2nd Ed. C.V. Mosby Co.

Tietge, J.E., R.D. Johnson and H.L. Bergman. 1988. Morphometric changes in gill secondary _lamellae_ of brook trout (_Salvelinus fontainalis_) after long-term exposure to acid and aluminum. Can. J. Fish Aquat. Sci. 45: 1643-1648.

Tranter, D.J. 1958. Reproduction in Australian pearl oysters. II. _Pinctada albina_ (Lamarck): gametogenesis. Aust. J. Mar. Freshwtr. Res. 9: 144-158.

United States Department of Agriculture Research Service. 1970. Forage Fiber Analysis. Agric. Handbook No. 379.

Wilson, B.R. and E.P. Hodgkin. 1967. A comparative account of the reproductive cycle of 5 species of marine mussels (_Bivalvia_: _Mytilidae_) in the vicinity of Freemantle, W. Australia. Aust. J. Mar. Freshwtr. Res. 18: 175-203.

PART B: PRE-SPILL AND POST-SPILL CONCENTRATIONS OF HYDROCARBONS IN SEDIMENTS AND MUSSELS AT INTERTIDAL SITES WITHIN PRINCE WILLIAM SOUND AND THE GULF OF ALASKA.

Damage assessment of the oil spill in PWS and the GOA requires information on hydrocarbon contamination levels in water, sediment and biota prior to the spill (baseline), and at various times after the spill in order to determine the potential impact and duration of impact. Hydrocarbon baseline information is available for several sites in PWS prior to oil transport and for the first 4 years of oil shipment. The intertidal baseline for hydrocarbon levels in mussels, sediment, water, and fish had been established at 10 sites from 1977 to 1981. All sites are located on low energy, low gradient beaches, often at the head of embayments, and most sediments transects are associated with eel grass. All sites have adjacent bands of mussels (Mytilus trossulus).

Because of the potential persistence of hydrocarbons in sediments in temperate and subarctic intertidal and subtidal environments, sampling may be continued to document depuration and recovery. Concentrations of the full range of individual aliphatic and aromatic hydrocarbons in sediments and mussels from intertidal sites will be reported. Abundance of mussels and other epifauna along sediment and mussel transects will be photographically recorded during each sampling period. These data will provide a basis for estimating temporal and spatial impact to other biota of the nearshore environment.

OBJECTIVES

A. Sample and estimate hydrocarbon concentrations in mussels and sediment from 20 sites within 10% of the actual concentration 95% of the time, when total aromatic concentrations are greater than 200 ng/g dry wt.

B. Test the null hypothesis that hydrocarbon contamination of sediments and mussels is the same for the pre-spill and post-spill period.

C. Document changes in abundance and distribution of intertidal epifauna and test the null hypothesis that no differences occur at oiled and non-oiled sites.

METHODS

Ten intertidal sites in PWS and Port Valdez were sampled for sediments, mussels, water, and fish annually from 1977 to 1981 to establish a baseline against which future changes in hydrocarbon concentrations can be compared. Sites were initially sampled in spring, summer and fall to determine if short-term changes occurred during the warm season. These sites were resampled in March of 1989, immediately before several of them were impacted by the EVOS.

Ten additional sites were established to cover areas in the trajectory of the oil path. Four of these sites were on the Kenai Peninsula (KP) and the remaining six were in PWS. Sediment and mussel samples were taken. Photo documentation was initiated along mussel and sediment transects at each site. These sites were re-sampled several times during the summer of 1989 to document the appearance of and changes in hydrocarbon contamination from the EVOS.

Sediments: Transect lines thirty meters (m) in length are located parallel to the water line at -0.75 m to +0.75 m (depending on specific site). Sediment samples will be collected in triplicate at each site by compositing 10 cores (dia 3.2 cm x depth 1.25 cm) taken at random along a 30-meter transect for each sample. Composite sediments will be placed in chemically clean 4-oz. jars, placed in an ice chest with artificial ice and transported. These will be frozen within 2-3 hours of collection. One blank sample will be taken at each site.

Mussels: These transects are located in mussel bands, parallel to the water line, usually just above (~+1 m tide level) the sediment transects. Triplicate mussel samples will be collected by taking approximately 30 2-5 cm. mussels (enough to produce >10 gms tissue) at random along the 30-meter transect. Samples in 16 oz. jars will be cooled, transported and frozen in the same manner as the sediment samples.

Photo Documentation: Close-range views will be photographed of the strata, macroflora and epifauna. Photos will be taken every 4 or 8 m along the sediment transect and every 2 or 4 m along the mussel transect line beginning at 1 meter. Macrophyte cover as well as epifaunal occurrence and density will be recorded from photographs taken of 625 cm2 quadrants placed along the sediment and mussels transect lines. A grid of 100 random dots projected on each slide will be used to estimate the occurrence and percentage of surface area covered by macrophytes and epifauna. Macrophytes and epifauna will be identified to species where possible.

Data Analysis:

Random sample and subsample collection will ensure that hydrocarbons present in the sample represent the average concentration at each site. "Hot spots" of hydrocarbon concentration over the 30 meter transects should be canceled out by this procedure. Selected triplicate samples will be analyzed, the mean concentrations and deviations from these means determined, and appropriate statistical tests applied - either ANOVA or paired comparisons (Tukey or Sheffe' tests). Digital tables of individual hydrocarbons will be reported.

Macrophyte and epifauna occurrence and cover will be analyzed using one-way ANOVA or paired comparisons (oiled versus non-oiled where strata are similar). They will be tested at the .05 level of significance.

BIBLIOGRAPHY

Connell, Joseph H. 1970. A predator-prey system in the marine intertidal region. 1. Balanus gladula and several predatory species of Thais. Ecol. Monog. 40:49-78.

Gundlach, Erich R., Paul D. Boehm, Michel Marchand, Ronald M. Atlas, David M. Ward, and Douglas Wolfe. 1983. The fate of Amoco Cadiz oil. Science 221:122-129.

Karinen, John F., L. Scott Ramos, Patty G. Prohaska, and William D. MacLeod, Jr. In Preparation. Hydrocarbon distribution in the marine environment of Port Valdez and Prince William Sound, Alaska.

Warner, J.S. 1976. Determination of aliphatic and aromatic hydrocarbons in marine organisms. Anal. Chem. 48:578-583.

BUDGET: USFS

PART A:

Salaries	$ 56.0
Travel	14.0
Contracts	8,818.0
Equipment	65.0
Total	$ 8,953.0

PART B:

Salaries	$ 34.0
Travel	36.0
Contracts	82.0
Equipment & Supplies	8.0
Total	$ 160.0

BUDGET SUMMARY

ADF&G	$ 156.7
USFS	9,113.0
Total	$ 9,269.7

AIR/WATER RESOURCES INJURY ASSESSMENT

The evaluation of injury to air, water, and sediment resources is a critical component in assessing the overall damage to natural resources caused by the EVOS. Three studies addressing impacts on water column and bottom sediments will continue in the second year of the damage assessment effort. Air resources were studied in the first year immediately after the oil spill, but will not be continued because of the short term impact to the air resource.

Water and Sediment Resources

Assessment of the concentrations of petroleum hydrocarbons in the water column of PWS and the Kenai Fjords region began almost immediately after the EVOS. Oil affected pelagic and nearshore waters, benthic sediments, intertidal habitats and adjoining habitats above high tide. Quantifying hydrocarbon levels in the water column was most critical during the first few weeks following the EVOS, when dissolution of soluble components was most rapid and the likelihood of toxic exposure was highest. As wind and current spread the oil and carried it farther away from the spill site, concern shifted from immediate impacts in the water column to longer-term effects from shoreline oiling on nearshore and subtidal sediments, and to chronic low-level hydrocarbon contamination of the water column.

Marine water quality is protected under state and federal water quality standards which include classifications for such uses as growth and propagation of fish and wildlife, aquaculture, and human uses such as recreation. Moreover, State of Alaska water quality standards for petroleum hydrocarbons establish criteria for water habitats.

The three water and sediment studies funded for this year are designed to reveal the continuing extent of hydrocarbon contamination remaining after the spill. Chronic, low-level contamination of the water column is expected to continue through the bleeding-off of oil from impacted shorelines. Nearshore and offshore sediments continue to be exposed to further contamination from the suspension and sinking of oily beach materials. Documenting the extent of continuing contamination will assist in demonstrating injury to the water resource along with chemical exposure of marine mammals, birds, intertidal and shallow subtidal communities, fisheries, and terrestrial mammals dependent on beach habitats.

The Air/Water (A/W) studies are integrated with the Coastal Habitat studies to provide data on injury to habitats for other studies that address injury to biological resources. A/W studies will also help establish the basis for restoration.

The three continuing water quality studies focus on:

1. Petroleum hydrocarbon-induced injury to subtidal marine sediment resources and injury to benthic infauna.

2. Geographic and temporal distribution of dissolved and particulate petroleum hydrocarbons in the water column.

3. The toxicity of weathered oil and the fate and effects of oil transformation compounds within the marine environment.

A/W Study 1, which is not continued in 1990, documented the extent of the surface oiling, and mapped the results for use by other studies. Further oil fingerprinting will be conducted under response activities, or by Technical Services Study Number 1. A final report mapping the distribution of surface slicks in the first year of the spill will be produced this year.

A/W Study 2 is now combined with elements of A/W Study 4 into one integrated sediment contamination study. This study will continue to document the presence, persistence, and chemical composition of petroleum hydrocarbons in subtidal marine sediments. These data will assist in quantifying injury to the sediment and will provide the chemical linkage needed to assess biological injury. Shallow subtidal oil concentrations will be compared with oil concentrations in adjacent intertidal areas to better understand the fate of oil. This study will continue to determine the degree of injury to the benthic infaunal resource and the duration of any documented injury. Additionally, microbial screening techniques of subtidal sediments will be employed to determine the presence, toxicity, and degradation rates of oil. Sediment sampling stations extend outside PWS to include the Kenai Fjords, Katmai, Cook Inlet, Kodiak, and the Aleutian Chain.

A/W Study 3 will continue to document hydrocarbon concentrations in the water column at a range of depths and locations. Trends in ambient water quality will be determined using the blue mussel as a biological indicator of low-level, chronic water quality contamination to supplement chemical measurements. Sediment traps will be deployed to measure sedimentation and associated hydrocarbon inputs to subtidal sediments.

A/W Study 5 was completed.

A/W Study 6 is a new study designed to address the concerns for long-term contamination and toxicity of weathered oil and its degradation products to selected test organisms, and to integrate the results of several projects into a mass-balance budget for the distribution, transport, transformation, and persistence of spilled oil in Alaska coastal environments.

AIR/WATER STUDY NUMBER 2

Study Title: Petroleum Hydrocarbon-Induced Injury to Subtidal Marine Sediment Resources

Lead Agency: NOAA, State of Alaska

INTRODUCTION

A proportion of the oil that entered the water (either the original crude oil derived from the spill, oil leaching from contaminated shorelines, and/or oil dispersed into receiving waters via shoreline remediation procedures) probably has reached, or will reach, the bottom as a result of physical (Boehm et al. 1987) and biological processes.

Benthic data collected in polluted waters elsewhere suggest that changes in number and diversity of species, as well as abundance and biomass of species, can be expected if sizable amounts of oil settle to the bottom. These changes can have serious trophic implications since many subtidal benthic invertebrates are important food resources for bottom-feeding species such as pandalid shrimps, crabs, bottomfishes and sea otters. Further, the larvae of most benthic organisms in PWS move into the water column (in March through June) and are utilized as food by large zooplankters and larval and juvenile stages of pelagic fishes, small salmon fry, and herring. Thus, damage to the benthic system by hydrocarbon contamination can affect feeding interactions of important species both on the bottom and in the water column.

Continuation of this study will evaluate the extent of subtidal hydrocarbon contamination in PWS, along the LKP, and near Kodiak Island. The purpose of this study will be to determine to what depth petroleum hydrocarbons have been transported over the winter months of 1989/90, to continue the time-course of data acquisition necessary to answer the question of persistence of petroleum hydrocarbons in subtidal sediments, and to determine the impact of oiling upon subtidal resources. Fewer sites will be studied this year. However, intensity of sampling will be increased.

Three projects formerly funded under A/W Study 4 will be included in this study. The first enumerates hydrocarbon oxidizing bacteria and assesses the maximum potential for 'in situ' biodegradation of selected hydrocarbons at various sites within and outside of PWS. Coupled with data on ambient hydrocarbon concentrations, the microbial data will allow a gross estimate of the maximum possible rate of bacterial hydrocarbon oxidation 'in situ' to be made. The second project will screen sediments for petroleum hydrocarbons using ultra-violet fluorescence spectrophotometry and will assess the toxicity of marine sediments using the luminescent marine bacterium <u>Photobacterium phosphoreum</u> to test for aqueous toxicants

(Schiewe et al. 1985). The third project titled "Injury to Deep Benthos" will examine the injury, if any, to infaunal communities below a depth of 20m in bays adjacent to eel grass beds. The sampling for all projects included in A/W Study #2 will be conducted from the same vessel and time (June, July). The present study will also coordinate closely with the subtidal project of the Coastal Habitat Study. Sediment and microbiological samples will be collected at the identical eelgrass sites where the Coastal Habitat study will sample shallow subtidal benthos.

OBJECTIVES

A. Determine occurrence, persistence, and chemical composition of petroleum hydrocarbons in subtidal marine sediments.

B. Provide marine sediment data to assist agencies in mass balance calculations on the fate of oil in the marine environment.

C. Relate subtidal oil concentrations to adjacent intertidal concentrations.

D. Screen sediments for oil contamination and estimate the toxic effects of petroleum hydrocarbons using bacterial bioassays of sediment samples collected from oiled and nonoiled habitats.

E. Enumerate hydrocarbon oxidizing bacteria and assess the maximum potential for 'in situ' biooxidation of selected hydrocarbon substrates in subtidal marine sediments at oiled and nonoiled sites within and outside of PWS.

F. Determine if changes occurred in the macro-benthos by comparing species richness, species diversity, general abundance and biomass, and trophic composition of the benthic biota living on similar substrata at approximately 40, 100, and >100m below sea grass beds between oiled and unoiled bays.

G. Determine if temporal changes will occur in the macro-benthos between oiled and unoiled bays by comparing species richness, species diversity, general abundance and biomass, and trophic composition of the benthic biota at specific stations.

H. If changes are detected in the infauna, examine the relationship between the accumulation and retention of hydrocarbons in sediments and the effect on the benthic biota.

METHODS

The methods employed by the three agencies cooperating in this study are described separately below.

National Marine Fisheries Service:

Auke Bay Laboratory

Sediments will be sampled at 16 sites in PWS (four reference sites and 12 contaminated sites). Sampling will be conducted during three periods (May, June/July and September). Six sites will be the same as those to be sampled by the subtidal project of Coastal Habitat Study. Outside PWS eight sites will be sampled. Six sites will be on the Kenai Peninsula and two sites will be near Kodiak Island. These sites will be sampled in July.

Three samples, each a composite of eight subsamples collected randomly along a 30 m transect laid parallel to the shoreline will be taken at each intertidal site. These samples will be collected at low tide or by divers. Intertidal collections will be made at a single tidal height in the range of +1 to -1 m relative to mean lower low water (MLLW) depending on the distribution of fine sediments.

Subtidal sediment collections will be made at depths of 3, 6 and 20 m below MLLW in May and September and at 3, 6, 20, 40 and 100 m in June/July. Collections at 3, 6 and 20 m will be made by divers on transects laid along the appropriate isobath and sampled in the same way as described above for the intertidal transects. The subtidal project of Coastal Habitat Study Number 1 will sample sediments, infauna and epifauna in the same depth range at six of the PWS sites. Samples taken at depths below 20 m will be collected with a Haps corer. A Smith-McIntyre grab will be used to sample those sediments which cannot be effectively sampled with the Haps corer. Three cores will be taken at each depth. Four subsamples will be removed at randomly selected points within each core. The subsamples will be combined to form one sample per core. The samples will be taken at the same sites as the benthos (see deep benthos sampling methods below), however sediments will not be taken from the same core/grab as the benthos samples because the volume removed for sediment hydrocarbon analysis will jeopardize the quality of the benthos samples.

Northwest Fisheries Center

Surface sediment samples for establishing levels of petroleum hydrocarbon residues and sediment-associated toxicity will be collected June through July, 1990 (Table 1). Sites will be located in potentially oil-impacted areas and also in unimpacted areas in PWS and LCI.

Selected sediment samples will be analyzed for petroleum hydrocarbons and other organic contaminants. After rapid extraction of sediments, relative aromatic hydrocarbon levels in sediment extracts will be measured using liquid chromatography coupled to a fluorescence detector. Sediment toxicity will be estimated using the Microtox bioassay that utilizes the luminescent marine bacterium Photobacterium phosphoreum (Schiewe et al. 1985). The test involves exposing suspensions of the bacterium to saline solutions of organic solvent extracts of sediment samples and measuring the effect of exposure on the amount of light emitted from the bacteria. The results of the test can be used to rank the relative toxicity of sediment samples. The relationship between Microtox results and contaminant levels in sediments will be used to provide support for the rankings of sediment toxicity by the Microtox bioassay.

Sampling activities will be conducted at 27 sites in PWS and LCI, including oiled and nonoiled sites (Table 1). Samples will be collected at water depths of 0 (intertidal), 3, 6, 20, 40, and 100 meters. At each site, sediment samples will be collected with a box corer, Van Veen or Smith-McIntyre grab. Each of three replicate sediment subsamples for each depth will be placed in two 20 ml scintillation vials and stored at - 20° C. The coordinates and depths of each station will be recorded.

Three sediment replicates are composited, the excess water is decanted and the sediment is stirred to homogenize and placed into a tared 100-ml centrifuge tube. Sodium sulfate, methylene chloride, and activated copper are added. Clumps are broken up with a teflon stirring rod, if necessary. Each tube is capped tight enough to prevent leakage. Each mixture is placed in a sonic bath or sonicated with a sonic probe. The sonicated samples are centrifuged for 5 minutes at 1,500 rpms. Each extract is then decanted into 50-ml labeled concentrator tubes. To the sediment remaining in the centrifuge tubes, another 10 ml of methylene chloride is added. The mixture is stirred with a teflon rod, capped, and sonicated in bath or with probe and centrifuged for 5 minutes. The solution is decanted into the original concentrator tube, another 10 ml methylene chloride is added, stirred, and sonicated and centrifuged again as described previously. The third extract is added to the first two, a boiling chip is added and the solution concentrated to exactly 10 ml. The sample is divided into two 5.0-ml portions, one for HPLC screening and one for Microtox analysis.

To the sediment portion for high pressure liquid chromatography (HPLC), polystyrene internal standard is added and about 1 ml of the mixture is transferred to a vial for the autosampler (the remainder is stored in another vial in the freezer). The analytical procedure for the detection of aromatic hydrocarbons (AH) in the sediment is similar to that of Krahn et al. (1988a,b), but analytical columns, are used instead of preparatory columns. The sediment extract (150 ul) is injected onto the HPLC columns and isocratically eluted with methylene chloride. The internal standard is detected with a UV detector and the aromatic compounds with a fluorescence detector (phenanthrene wavelengths--260/380 nm and an additional wavelength pair to be selected). To quantitate the total Ahs, the total fluorescence area is integrated during the time when the fraction would be collected for the prep cleanup (Krahn et al. 1988b) and converted to phenanthrene equivalents (the concentration of phenanthrene that would result in an equivalent integrated area) or to other AH equivalents, respectively (as determined from above).

Initially, dose-response studies using oil and oil-contaminated sediments will be evaluated by the Microtox bioassay in conjunction with the ultraviolet fluorescence (UVF) screening methods. Subsequently, five ml of each sediment extract in methylene chloride will be obtained as described. Samples (volumes will be determined in the dose-response studies) will be exchanged into 1 ml of ethanol by solvent evaporation under constant heat. Microtox assays of the organic extracts will then be conducted as described in the Puget Sound Estuary Program protocols for sediment bioassays (EPA 1988).

Alaska Department of Environmental Conservation:

Microbiology sediment samples from the intertidal and shallow subtidal areas will be obtained from the shore parties and divers collecting samples for hydrocarbon chemistry analysis. Microbiology samples from deeper subtidal areas will be obtained from the core or grab sampler at the same stations and times as those collected for chemistry analysis.

Sediment samples for microbiological analysis will be collected in sterile Whirlpak bags as composites in triplicate along the same horizontal transects from which the chemistry samples are obtained. Care will be taken to avoid contamination of samples by the sampling personnel and cross-contamination between different sediment samples. Sampling apparatus should be thoroughly rinsed with water between samples and, where possible, disinfected with alcohol or other disinfectant. Samples obtained from the deeper water grabs will be collected from the center of the core to avoid surface contamination incidental to sample handling.

Hydrocarbon biodegradation potential associated with sediment microbes will be assayed by adding radiolabelled aliphatic and aromatic substrates to sediment samples. (^{14}C)-hexadecane, (^{14}C)-phenanthrene and (^{14}C)-benzo[a]pyrene will be the three hydrocarbons substrates used. Each substrate will be monitored for biodegradation by the evolution of radio-CO_2 from the samples after two incubation periods. The incubation periods will be chosen appropriately to show biodegradation activity for the given substrate (e.g., the benzopyrene incubations will be longer than for hexadecane).

A total of 20 grams of sediment from each sample will be needed for this assay. Each sediment sample assayed for hydrocarbon degradation will first be mixed 1:10 with sterile seawater augmented with mineral nutrients. Ten ml aliquots of the resulting slurry will then be placed in sterile 40-ml incubation vials fitted with silicone septa. For each substrate, on selected sediment samples, two concentrations will be used to investigate the effect of hydrocarbon concentration on biooxidation rates. The substrate of interest will be added at either 1 or 10 ppm (ug/ml slurry) concentrations by injection via syringe through the septa. The substrates will be added in an acetone carrier (Bauer and Capone, 1988). Two replicate vials for each substrate/sediment sample/incubation time combination will be prepared with a "time zero" killed control also prepared for each substrate and triplicate set. All vials will be placed on a rotatory shaker for 24 hours and then incubated at ambient temperatures for the duration of the incubation period.

Following incubation of the sample for the appropriate period (or initially in the case of the controls), substrate biodegradation in the sample vials will be halted by the addition of 1 ml 10N NaOH through the septum. This will result in a Ph greater than 13, killing the culture of degraders and sequestering any evolved CO_2 in the form of carbonates in solution. The extent of hydrocarbon degradation will be monitored by measuring the radio-CO_2 evolved from each vial (Foght et al., 1989). After transport to the analytical facility at the University of Alaska, the sample vial contents will be acidified by addition of concentrated HCl via syringe through the septum. The headspace will be purged of radio-CO_2 and the effluent gas will be passed first through an organic vapor trap and then through phenethylamine scintillation cocktail to trap the evolved CO_2 (Fedorak et al., 1982). The mean of each set of biodegradation samples for each substrate, concentration and incubation period will be compared with the "time zero" controls to assess for losses due to volatilization in transit or any possible abiotic CO_2 evaluation. The extent of biodegradation will be expressed as a percentage of the total radiocarbon added to the sample after correction for abiotic losses and ambient hydrocarbon concentrations.

In addition to the biooxidation potential assay, populations of hydrocarbon oxidizing bacteria will be enumerated using a "dilution to extinction" technique. The Most Probable Number (MPN) statistical enumeration technique, as modified for oil degrading bacteria and shipboard space constraints (e.g., using sterile, 24-well tissue culture plates), will be used.

Aliquots of slurry taken from the dilution bottles generated for the biooxidation potential study will be serially diluted ten-fold several times, giving a range of dilutions from 1:10 to $1:10^9$. Five replicate 100-ul aliquots of these dilutions will be placed into the microliter plates' wells filled with sterile, carbon-free marine broth, producing five identical inoculations of each dilution. Then a "drop" of sterile Prudhoe Bay crude oil will be added to each inoculation well. The crude oil serves as the sole carbon source for any bacteria in the inoculum, selecting only those able to grow on crude oil. A positive indication of growth will be emulsification of the slick formed on addition of the oil to the wells. The most probable number of hydrocarbon degraders will then be calculated using a standard MPN table.

University of Alaska:

Five replicate samples will be taken at each of three stations within six bays identified as oil-exposed sites and at three stations within six bays determined to have been uncontaminated (control) sites. All stations sampled will be at approximate depths of 40, 100, and >100m on a transect extending below seagrass (Zostera) beds within each of the identified bays. The intertidal and shallow subtidal stations on the transect will be sampled for biota. A total of 36 deep stations x 5 replicates will be collected on a single cruise in early July in conjunction with microbiological and hydrocarbon sampling projects that will be underway from the same ship platform at the same or at approximately the same time. Benthic samples at oil-exposed and unexposed sites will be collected on bottoms that are as physically similar as possible, based on chart and fathometer data and preliminary grab samples to be made before actual sampling occurs. Considerable amounts of ship time might occasionally be required at some sites to ensure that similar bottom types are compared between oiled and control sites.

The six oil-exposed sites that will be sampled for deep benthos are Northwest Bay, Disk Island, Herring Bay, Bay of Isles, Snug Harbor, and Sleepy Bay. The six unexposed (control) sites to be sampled are West Bay, Rocky Bay, Zaikof Bay, MacLeod Harbor, and two sites to be selected prior to the July cruise.

The benthic biological samples from approximately 40, 100, and >100m will be collected with a 0.1m^2 van Veen grab weighted with 31.7 kg of lead to facilitate penetration. Five replicate samples will be taken at all stations. Material from each grab will be washed on nested 1.0 mm steel screens and preserved in 10% formalin-seawater solution buffered with hexamine.

DATA ANALYSIS

The null hypotheses to be tested will depend on which of the objectives listed above is under consideration. In general, for sediment analyses the null hypothesis will state that the concentration of petroleum hydrocarbons at particular depths or the distribution of petroleum hydrocarbons with depth at oiled sites does not differ from that at reference sites. All data will be tested for heteroscedasticity with Bartlett's test or equivalent.

Data will be reported as means and 95% confidence intervals calculated according to a standard formula (Sokal and Rohlf 1981). Parametric statistics (Model I analysis of variance with site and depth as fixed factors and Scheffe's a posteriori test) will be used to test for differences in hydrocarbon concentrations between sites and depths if underlying assumptions of the parametric procedures are met (with data transformation if required), otherwise nonparametric tests (eg. the Kruskal-Wallis test) will be employed. Key petroleum weathering and source ratios will be calculated (Boehm et al. 1987).

The relationship of sediment toxicity to luminescent bacteria at the study sites and hydrocarbon concentrations determined in sediment will be compared statistically using appropriate tests (Sokal and Rohlf 1981). Where significant differences are found, the α value will be understood to be < 0.05.

Analysis of the data on the deep benthos will be completed using previously written programs at the University of Alaska for comparison of species (taxa), rank abundance and rank biomass of species (taxon). A diversity program will also be used to examine differences and similarities between stations. Station groups and species (taxon) assemblages for each year and for the combined data collected on cruises in future years will be identified using the technique of hierarchical cluster analysis. Principal coordinate analysis will be used as an aid in interpretating of the cluster analysis of the data and in identifying misclassifications of stations by cluster analysis. Use of both of these multivariate techniques makes it possible to examine similarities (or dissimilarities) between groups of stations, and will be useful when comparing oiled vs unoiled bays.

A Kruskal-Wallis and a multiple comparison test for significance will be used to test for differences in the total abundance and biomass between the stations sampled in each year and in the multi-year data sets. These same tests will be made on the abundance and biomass of selected, dominant taxa at stations between years. The taxa will be chosen from the rank abundance and biomass printouts for each station, and taxa selected will generally be those commonly present within bays being compared. However, taxa that are common at stations within unoiled bays, but rare or missing at stations within oiled bays, will also be tested. Other statistical tests, such as the two-tailed Wilcoxon signed ranks test for pairwise observations, will be used to test differences between stations at similar depths and bottom type within unoiled and oiled bays.

Various measures of diversity will be calculated, and compared qualitatively between stations at similar depths within unoiled and oiled bays. The indices to be calculated and presented are: Shannon Diversity (measures total diversity), Simpson Dominance (useful for identifying dominance by one or a few taxa at a station), Evenness, and Species Richness.

The calculation of K-dominance curves for the abundance and biomass data will be used in an attempt to assess the effect of hydrocarbons on benthic organisms in oiled bays. This is a technique designed to detect pollution-induced disturbance on marine benthic communities. Distributions of geometric classes of abundance of species will also be calculated. Assessment of the distribution of taxa in these abundance classes is often useful to identify indicator species within a disturbed area.

The goal of the data analysis in this study is to determine the effects of short and long-term accumulations of petroleum hydrocarbons on benthic species composition, species diversity, abundance, biomass, and trophic composition. The critical aspect of the study is whether concentrations of petroleum contaminants from the EVOS are present at concentrations which cause deleterious effects on benthic organisms. Because the "deleterious effects" criteria are complex and often require subjective interpretation, a detailed comparison is ultimately required of the hydrocarbon concentrations at which various biochemical, behavioral, physiological, organismal, population, and ecological effects occur. This only addresses certain aspects of the organismal, population, and ecological effects on the benthic infauna.

BIBLIOGRAPHY

Abelson, P. H. 1989. Oil spills. Science 244:629.

Bauer, J.E. and D.G. Capone. 1988. Effects of co-occurring aromatic hydrocarbons on degradation of polycyclic aromatic hydrocarbons in marine sediment slurries. Appl. Env. Micrbiol. 54:1644-1655.

Boehm, P. D., M. S. Steinhauer, D. R. Green, B. Fowler, B. Humphrey, D. L. Fiest, and W. J. Cretney. 1987. Comparative fate of chemically dispersed and beached crude oil in subtidal sediments of the arctic nearshore. Arctic 40, supp. 1: 133-148.

Environmental Protection Agency. 1987. Recommended protocols for sampling and analyzing subtidal benthic macroinvertebrate assemblages in Puget Sound. Environmental Protection Agency, Final Report TC-3991-04.

Fedorak, P.M., J.M. Foght, and D.W.S. Westlake. 1982. A method for monitoring mineralization of 14C-labeled compounds in aqueous samples. Water Res. 16:1285-1290.

Foght, J.M., D.L. Gutnick, and D.W.S. Westlake. 1989. Effect of Emulsan on biodegradation of crude oil by pure and mixed bacterial cultures. Appl. Env. Microbiol. 55:36-42.

Hoberg, M. K. 1986. A numerical analysis of the benthic infauna of three bays in Prince William Sound, Alaska. M.A. Thesis, Humboldt State University, Arcata, CA 153 pp.

Krahn, M.M., L.K. Moore, R.G. Bogar, C.A. Wigren, S-L, Chan, and D.W. Brown. 1988a. A rapid high-pressure liquid chromatographic method for isolating contaminants from tissue and sediment extracts. J. Chromatography. 437:161-175.

Krahn, M.M., C.A. Wigren, R.W. Pearce, L.K. Moore, R.G. Bogar, W.D. MacLeod, Jr., S-L, Chan, and D.W. Brown. 1988b. Standard analytical procedures of the NOAA National Analytical Facility. New HPLC cleanup and revised extraction procedures for organic contaminants. U.S. Dep. Commer., NOAA Tech. Memo NMFS F/NWC-153, 52 p.

Schiewe, M.H., E.G. Hawke, D.J. Actor, and M.M. Krahn. 1985. Use of a bacterial bioluminescence assay to assess toxicity of contaminated marine sediments. Can. J. Fish. Aquat. Sci. 42:1244-1248.

Science Applications International Corporation. 1989. Screening analysis for petroleum hydrocarbons in sediments and sediment pore waters by use of ultra-violet fluorescence spectrophotometry for Exxon Valdez damage assessment. Draft Final Report No. SAIC-89/7570&230 to the National Oceanic and Atmospheric Administration. 36p.

Sokal, R. R. and F. J. Rohlf 1981. Biometry. W. H. Freeman and Company, San Francisco. 859pp.

Table 1. Location of sites in PWS and the GOA where intertidal and subtidal sediment and biological samples will be collected in 1990. Samples of hydrocarbon-degrading bacteria will be collected at all sites in each sampling period. Samples for microtox bioassay will be collected at all sites in June/July only. Deep benthos (D) will be collected at selected sites in June/July. Depths to be sampled are: A = intertidal (I), 3, 6 and 20 m; C = I, 3, 6, 20, 40 and 100 m.

Location	May	June/July	Sept
<u>Prince William Sound</u>[1]			
Bay of Isles	A	C,D	A
Block Island	A	C	A
Chenega Island	A	C	A
Disk Island	A	C,D	A
Fox Farm	A	C	A
Green Island	A	C	A
Herring Bay	A	C,D	A
Macleod Harbor	A	C,D	A
NE Knight Island	A	C	A
NE Port Fidalgo	A	C	A
Northwest Bay	A	C,D	A
Olsen Bay	A	C	A
Rocky Bay	A	C,D	A
Sleepy Bay	A	C,D	A
Smith Island	A	C	A
Snug Harbor	A	C,D	A
West Bay	A	C,D	A
Zaikof Bay		C,D	A
<u>Gulf of Alaska</u>			
Agnes Cove		C	
Black Bay		C	
Chugach Bay		C	
Hallo Bay		C	
Katmai Bay		C	
Sunny Cove		C	
Tonsina Bay		C	
Windy Bay		C	

1. Two additional sites will be selected before June 1990 to provide additional control sites for the deep benthos project.

BUDGET

NOAA

Salaries	$159.8
Travel	20.9
Contracts	53.0
Supplies	50.5
Equipment	32.6
Vessel	150.0
Total	$466.8

ADF&G

Salaries	$174.7
Travel	5.7
Contracts	124.9
Supplies	23.1
Equipment	5.1
Total	$333.5

AIR/WATER STUDY NUMBER 3

Study Title: Geographic and Temporal Distribution of Dissolved and Particulate Petroleum Hydrocarbons in the Water Column

Lead Agencies: NOAA, DEC

INTRODUCTION

This study will continue to assess the geographic and temporal distribution of dissolved and particulate hydrocarbons in the water column and deposited in sediments resulting from the EVOS. Knowledge of these concentrations will determine whether violations of State of Alaska Water Quality Criteria have occurred, and will allow estimation of the exposure risk of subsurface marine biota to petroleum hydrocarbons. This study extends work begun within one week of the grounding of the Exxon Valdez and continued to date.

A. DEC

During the autumn of 1989 (November/December), DEC collected interstitial water samples at target sampling sites in PWS and deployed sediment traps at selected sites. It was determined that no further interstitial water sampling would be conducted in 1990. Studies related to hydrocarbonoclastic bacteria will be continued by AW 2. An increased number and distribution of sediment traps is planned.

B. NOAA

Trends in hydrocarbon concentration in the water column will be studied by analyzing the hydrocarbon body burden of transplanted bay mussels Mytilus trossulus. The use of a bioaccumulator provides a time integrated indication of hydrocarbons available in the water column. No further direct sampling of the nearshore water column will be done because hydrocarbon concentrations in the water column will likely be below detection levels in field samples that are practical to analyze.

The products of this study will consist of estimates of aliphatic and aromatic hydrocarbons in the matrices examined. These data will be used to determine biological resource exposure to petroleum hydrocarbons.

This study is coordinated with the other A/W studies and with the CH 1 to provide information on petroleum hydrocarbon distribution and movement in the nearshore water column to researchers assessing biological and economic damage. In the 1990 field season this study will share research platforms with AW 2 and FS 24. Several sites of this study will coincide with sites from these two studies and with at least one CH 1 subtidal control site. Data gathered at these joint sites will provide a comprehensive picture of damage and will be especially valuable to studies assessing biotic and economic damage. Selection of NOAA AW 3 study sites was aided by information produced by AW 1 and AW 4 (now part of AW 2). Information on beach cleanup at study sites will be obtained from the DEC Spill Response Office and NOAA HAZMAT.

OBJECTIVES

A. To determine if sediments settling out of the water column in nearshore subtidal environments contain absorbed hydrocarbons (DEC).

B. Determine hydrocarbon inputs in nearshore environments and evaluate trends in ambient water quality using mussels (Mytilus trossulus) as bioaccumulators (NOAA/NMFS).

METHODS

A. DEC

Subtidal particulate samples will be collected with sediment traps for hydrocarbon analysis. Sampling arrays containing three sediment traps each will be placed in the subtidal zone adjacent to target shorelines at no more than 20 meters below mean lower low water. Results will generate information on sedimentation and associated hydrocarbon inputs to subtidal sediments.

Currently, five sediment trap arrays are in place in four locations in PWS: Sleepy Bay, Snug Harbor, Northwest Bay (2), and Northeast Port Fidalgo. Each platform consists of three removable long-term sediment traps. These traps will be picked up, and the number and distribution of the traps in PWS will be increased. Sediment traps will be placed in as close proximity as possible to the mussel cages being deployed in the NMFS segment of this study. Approximately fifteen additional emplacements (3 traps per site) are proposed. Sediment trap arrays will be deployed in relation to shoreline habitat types, according to the Environmental Sensitivity Index (Gundlack and Hays 1982), in conjunction with bioaccumulation where possible, and in relation to shoreline treatment methods as deemed feasible.

Particulate samples from sediment traps will be screened for hydrocarbon content by ultraviolet fluorescence spectrophotometry after methylene chloride extraction of the samples in the field. UVF is a semiquantitative method of analysis for hydrocarbons (ASTM, 1982). Samples showing significant quantities of petroleum hydrocarbons will be further analyzed for polynuclear aromatic hydrocarbons (PAH) and total petroleum hydrocarbons (PHC) according to procedures established by TS 1.

B. NOAA/NMFS

Mussels will be placed at all 1989 sites within PWS (Figure 1) except Squire Island and The Needle. Except for Olsen Bay (control), all sites were in the spill trajectory and subject to varying degrees of oiling. Redeployment this year will indicate changes in water column hydrocarbon concentrations at these sites since deployed mussels were last collected in September 1989. Seven additional sites are proposed: four at sites of maximum original oiling as indicated by preliminary analysis of water column samples (AW 3) and sediment pore water samples (AW 4), and at Disk Island and Black Island where extensive cleanup activity is anticipated. Mussels will also be deployed at a second control site, McCleod Bay.

Outside PWS, redeployment is proposed at Sunny Cove (Resurrection Bay), Black Bay, Tonsina Bay, Blue Fox Bay (Afognak Island), Hallo Bay and Kukak Bay (control) (Figure 2). The two new sites, Agnes Cove and Windy Bay, are coincident with AW 2 sites.

Local siting will ensure a site depth of 34 m (to accommodate the deepest mussel cage) and the best available protection from prevailing weather and currents. Site substrates will be cobbled to finer sediments to ensure that mooring anchors are set securely. If treatment activity occurs, siting may be adjusted or additional sites may be added so that beaches adjacent to sites represent both treated and untreated beaches.

Physical data on location (geographic coordinates), site depth, sampling time, tidal stage, and temperature and salinity at deployment depths will be recorded at each site.

Bay mussels will be collected from a hydrocarbon free site, Admiralty Island in southeast Alaska, a few days before each new deployment cruise. Mussels will be held in living stream tanks, that have been rinsed with dichloromethane and flushed with ambient unfiltered seawater at the rate of 2 liters/minute at least overnight. Since mussel size influences hydrocarbon uptake (Bayne et al., 1981), only mussels with shell length of 45-50 mm will be selected for deployment. A sample from each collection of at least 30 individuals will be measured for shell length, width, and height and whole wet versus dry weight. Another 40-50 animals will be taken immediately prior to shipment of mussels to a deployment vessel as a reference sample of the population's base hydrocarbon level and condition.

Mussels will be shipped to the field in layers of healthy <u>Fucus sp.</u> seaweed in insulated coolers whose lids have been drilled with air holes. Mussels will be kept aboard the deployment/collection vessel in coolers and the blue ice changed daily for up to 6 days. On longer cruises, mussels will be resupplied by air or possibly irrigated with the seawater. Samples of irrigation water will be taken daily, extracted with dichloromethane,and frozen. A mussel baseline sample will be taken before deployment of irrigated mussels at each new site.

A deployment "cage" is a nylon mesh diver collecting bag held open by a perforated polypropylene sheet that has been rinsed with dichloromethane and fitted into the bag bottom. Twenty mussels will be placed in each bag separately (i.e. byssal connections to other mussels will be separated so that byssal development observed when mussels are collected will have occurred during field exposure.) Assuming some mortality during exposure, this number was chosen to provide at least triplicate samples of 3 ± .5 g of issue for hydrocarbon analysis (Krahn et al 1988). At 4 sites in PWS an extra cage containing 40 mussels will be deployed at 1 m to be exposed for 8 to 10 weeks so that hydrocarbon uptake over the longer period may be compared with uptake over the 2 shorter periods at the same site. Filled bags will be closed and attached to the mooring line with a halibut snap. At each site, bags will be attached at the 1 m, 5 m, and 25 m depths. The 2 shallower cage depths were chosen to correspond to water column depths sampled by this study in the first 6 weeks after the spill; mussels at the third depth will be exposed to the water column about 10 m above the bottom at low tide. Reference samples of mussels will be taken just after the final deployment on a cruise to determine any hydrocarbon uptake or deterioration of general condition during holding of mussels on the vessel. Exposure times will be 4 to 5 weeks, and 8 to 10 weeks at the four selected sites. There will be three periods of exposure at PWS sites and one period at Kenai, Afognak and Alaska Peninsula sites.

After exposed mussels are retrieved, the number of clumps of mussels, the number of individuals per clump, comments regarding the strength and elasticity of byssal threads, and the number of alive, dead, or gaping animals will be recorded. Dead or gaping animals will discarded. At least 1 hydrocarbon free 16 oz jar with a Teflon lid will be filled with live animals from each bag, kept in a cooler, and frozen at -18 °C as soon as possible. A field air blank will be taken at the site and on the vessel, if sample jars are filled aboard the vessel. Mussel cages will then be refilled and redeployed.

Naturally occurring adult mussels will be collected in intertidal areas adjacent to some deployment sites. These will be packed in clean 16 oz jars and handled similarly to caged mussel samples.

Sample estimates are: 236 caged exposed mussel samples, 59 air blanks, 20 native mussel samples, and 15 reference samples.

DATA ANALYSIS

A. DEC

Hydrocarbon concentration data will be tested for heteroscedasticity (Bartlett's test) and reported as means and 95% confidence intervals calculated according to a standard formula (Sokal and Rohlf, 1981). Parametric statistics will be used to test for differences between hydrocarbon concentrations between sites, if the assumptions of parametric procedures are met. Otherwise, nonparametric tests (e.g., the Kruskal-Wallis test) will be employed.

B. NOAA/NMFS

ANOVA will be used to determine the significance of differences of any hydrocarbons found in the collected samples.

Products of this study will consist of tables containing lists of hydrocarbons found in the samples collected.

BIBLIOGRAPHY

ASTM D-3650-78. Standard Test Method for Comparison of Waterborne Petroleum Oils by Fluoresence Analysis.

Bayne, B.L., K.R. Clarke and M.N. Moore. 1981. Some practical considerations in the measurement of pollution effects on bivalve molluscs and some possible ecological consequences. Aquatic Toxicology 1:159-174.

Gundlach, E.R. and M.O. Hayes. 1982. The oil spill environmental sensitivity index applied to the Alaskan coast: in 1982 Arctic Marine Oil Pollution (AMOP) Seminar. Edmonton, Alberta, Canada. pp.311-323

Krahn, M.M., C.A. Wigren, R.W. Pearce, L.K. Moore, R.G. Bogar, W.D. MacLeod,Jr., S. Chan, and D.W. Brown. 1988. Standard analytical procedures of the NOAA National Analytical Facility, 1988, New HPLC cleanup and revised extraction procedures for organic contaminants. NOAA Technical Memorandum NMFS F/NWC-153. 52 pp.

Sokal, R. R. and R. J. Rohlf. 1981. Biometry. Freeman, San Francisco.

BUDGET: DEC

Salaries	$ 19.6
Travel	1.4
Contracts	17.5
Supplies & Equipment	9.0
TOTAL	$ 47.5

BUDGET: NOAA

Salaries	$161.5
Travel	15.3
Contracts	12.3
Supplies	40.2
Equipment	43.2
Ship Costs:	200.0
TOTAL	$472.5
TOTAL both Projects	$520.0

AIR/WATER STUDY NUMBER 6

Study Title: Fate and Toxicity of Spilled Oil from the EVOS

Lead Agency: NOAA

INTRODUCTION

Overview and Relation to other Studies

This study is designed to: a) assess the toxicity of weathered EXXON VALDEZ oil and its degradation products to selected test organisms; and b) integrate the results from selected other projects into an overall budget for the distribution, transport, transformation, and persistence of spilled oil in Alaskan coastal environments. The study is very closely coordinated with A/W Study 2 for its field work and toxicity studies, and will require close interaction with all of the present and past A/W studies, the Coastal Habitat study, and with related spill response studies for completion of the spilled oil budget.

Toxicity of Crude Oil in Relation to the Weathering Process

Currently, limited information is available on the significance of either the polar constituents of crude oil or the intermediate oxidation products of petroleum hydrocarbons (whether from photooxidation or biodegradation) in terms of their potential for bioaccumulation and toxicity to resource organisms in the marine environment. Since these compounds have undergone preliminary oxidation and (sometimes) conjugation, they are more polar than their parent hydrocarbons, and will as a result generally be more subject to excretion or depuration, less subject to bioaccumulation, more susceptible to further oxidation (or biodegradation if accumulated), and more susceptible to dilution and dispersion in the water column. Studies proposed here are designed to help determine whether such polar constituents pose a significant risk of toxicity or mutagenicity to Alaskan marine organisms as a result of the EVOS.

Acute and Sublethal Toxicity of Oil to Marine Organisms

A very considerable body of literature exists on the toxicity of Alaskan crude oil to Arctic and subarctic marine organisms. The data base is probably adequate for assessing the relative sensitivities of different marine species to exposure and for estimating the range of potential responses (at the organismic level) that may result from a particular level of exposure in the environment. However, very little of this prior toxicity research has been directed specifically at the contribution of either hydrocarbon metabolites or other oxidation products of oil that may be produced by the processes of biological or chemical weathering in the environment.

Sources of Toxicity in Crude Oils

By the mid-1970's, it had been concluded that much of the acute toxicity of oil was accountable directly to the content of soluble aromatic compounds (Moore and Dwyer 1975; Neff et al. 1976), and attention was being directed towards determining which fractions of petroleum were most responsible for the toxicity observed in laboratory and field exposures to oil. Based on the relative concentrations of the low-molecular weight constituents in crude oil, it has become generally accepted that most of the acute toxicity effected by oil in the environment is derived from the mono- and di-nuclear aromatics. When a water soluble fraction (WSF) was simulated by mixing the 10 predominant aromatic hydrocarbons at the same concentrations and proportions found a true WSF of crude oil, however, the toxicity of the resulting mixture was only 20-30% of the true WSF, suggesting that either minor aromatic constituents, or components other than aromatic hydrocarbons, also contribute significantly to the observed toxicity (Rice et al 1984).

Polar Constituents and Oxidation Products of Oil

Petroleum in the marine environment is decomposed primarily through the processes of microbial biodegradation and photooxidation or autooxidation These processes are effective for oil in surface slicks, in the water column, in sediments, and in the atmosphere (photooxidation of evaporated compounds). In addition, parent petroleum compounds are bioaccumulated, and metabolized by macro-organisms. While the eventual major products of these oxidative reactions are carbon dioxide and water, some of the oxygenated intermediates produced along the way may be more toxic than their precursors.

Oxidation products of photooxidation include fatty acids, alkylated naphthols, and substituted 1- to 3-ring aromatic and heteroaromatic acids, as well as alkylated benzothiophene sulfoxides (Overton et al. 1979, 1980). Microbial biodegradation of alkanes, cycloalkanes, and monoaromatics leads to the production of alcohols, aldehydes, and carboxylic acids that are generally of little concern from a toxicity standpoint. Condensed polyaromatic hydrocarbons, however, may be transformed by microbial metabolism to potential carcinogens or mutagens. Materials such as benzo(a)pyrene and benzo(a)-anthracene, for example, are oxidized by eucaryotic organisms (macroorganisms, yeasts and molds) to trans-dihydrodiols which are subsequently activated into oxides that bind to DNA and are powerful mutagens.

Some metabolic products of high-molecular weight aromatics are demonstrated mutagens or carcinogens and have been shown to bind to DNA (Ahokas et al. 1979; Lech and Bend 1980; Varanasi et al. 1981). These same materials are also associated with the prevalence of liver lesions, including neoplasms (Varanasi and Stein 1990).

Asphaltenes and resins are two heterogeneous and poorly characterized assortments of (non-hydrocarbon) compounds that comprise only about 2% and 6%, respectively, of Prudhoe Bay crude oil (Clark and Brown 1977). Asphaltenes are constituents of tar that are highly resistent to biodegradation, and are not generally considered to pose a risk of toxicity to marine organisms. Resins include the polar and heterocyclic nitrogen sulfur oxygen (NSO) compounds, such as phenols, cresols, thiophenes, dibenzothiophenes, pyridines, and pyrroles. Some of them are likely to undergo biodegradation, and very broad suites of NSO compounds have been identified in contaminated marine environments (Krone et al. 1986, Wolfe et al. 1981). Like hydrocarbon metabolites, many of these compounds are moderately water-soluble and therefore subject to dispersion in the water column. While some of these polar compounds could be toxic at high concentrations, no studies have been made of the levels of toxicity exerted by these materials under oil spill conditions in the marine environment.

Fate of Spilled Oil: Budgets and "Mass Balance"

An accurate and complete mass balance has yet to be prepared for any major oil spill in a marine environment. The quality of estimates of the quantities and locations of oil affected by different processes of transport or transformation have varied from spill to spill, depending on the local circumstances of the spill and the effort devoted to any particular process. Selected observations at past spills have been summarized by Mackay (1981), Gundlach et al. (1983), Jordan and Payne (1980), National Academy of Sciences (1985), and Wolfe (1985, 1987). Information especially pertinent for summarizing the fate of oil from the EXXON VALDEZ spill has been and is being gathered by the Interagency Response Team and the ADEC, and by certain projects under the NRDA.

OBJECTIVES

A. Document the toxicity of contaminated sediments and related environmental samples to selected marine biota

B. At selected sites, document and quantify the occurrence of oxidized derivatives of EXXON VALDEZ oil

C. Determine the extent to which the observed toxicity of oil-contaminated environmental samples may be attributable to oxidation products of petroleum.

D. Construct a summary budget or "mass balance" summarizing the fate of the spilled oil.

METHODS

A. Toxicity of Oil-Contaminated Sediments and Other Environmental Samples

Toxicity tests will be performed on sediment samples taken at selected sites sampled by A/W Study 2. Two specific tests, both following well-established protocols, are proposed: a sediment elutriate test using larval mussels *Mytilus edulis*, and a whole sediment test using *Ampelisca abdita* (or other suitable Alaskan species of *Ampelisca*). *Mytilus* is an intertidal species whose larval recruitment is vulnerable to interruption by toxic oil residues remaining in intertidal sediments. *Ampelisca* inhabits soft nearshore sediments that are possible sinks for petroleum. Subtidal ampeliscid amphipods exhibited considerable sensitivity to oil in the aftermath of the AMOCO CADIZ spill (Cabioch et al. 1982). Use of these two species should provide a direct measure of the toxicity of the residual oil to actual marine species.

Sampling sites have been selected to represent the more heavily oiled areas. At each of 20 of the sites, eight one-liter samples of surficial sediments will be collected (2 each at the intertidal, 6-meter, 20-meter, and 100-meter depths) for toxicity testing with *Mytilus* and *Ampelisca*. These samples will be stored at 0-4 degree celsius and offloaded from the vessel at regular intervals for shipment to the testing laboratory. Bioassays will be initiated within 10 days of the collection of the samples.

B. Oxidation Products of Petroleum

The fractionation and toxicity testing of polar constituents from weathered petroleum will be pursued in a tiered, stepwise fashion. A limited pursuit of chemical fractionation and characterization will be undertaken in association with the toxicity testing to be performed under A/W2. This preliminary study will include two major objectives, and will employ the following approaches:

1. Determine whether the toxicity (if any) of organic extracts from Exxon Valdez oil-contaminated sediments is partitioned between polar and non-polar constituents:

Approach:

* perform microtox on unfractionated extracts
* perform one-step separation on PAC column to fractionate polar from non-polar constituents
* repeat microtox on the two separated fractions
* perform simple carcinogenicity/mutagenicity

bioassay (eg Ames test, S.O.S. Chromotest) on selected fractions

2. Determine what types of polar constituents are present in these extracts:

Approach:

* perform HPLC/UV on polar (and non-polar) fractions to identify presence of PNA derivatives
* perform detailed GC/MS on selected polar fractions to identify and quantify (major)constituents

The work should focus (a) on determining whether a significant fraction of the observed toxicity or mutagenicity can be ascribed to polar derivatives in a few of the most biologically active samples, and if so, (b) on a preliminary characterization of the polar constituents that may be involved. The selection of samples for this chemical fractionation and characterization will be guided by the magnitudes of the Microtox and UVF signals.

If this preliminary work suggests that polar constituents could account for significant toxicity in the marine environment, more intensive testing will be performed. At two heavily oiled sites, one untreated and one that has undergone bioremediation (both yet to be selected), and one lightly or unoiled site in PWS, special samples will be taken to assess the concentrations and compositions of petroleum oxidation products in intertidal sediments. These samples will also be taken in conjunction with A/W Studies 2 and 3, probably from the NOAA vessel COBB during the late summer or fall of 1990. Large quantities of sediments and/or interstitial water will be required to support the necessary development of suitable techniques for bulk fractionation of samples to be tested for toxicity (in C. below) and for chemical characterization and quantification of the polar metabolites.

Replicate (3) sediment samples on the order of 10kg (wet weight) each will be collected at each site for exhaustive extraction with methylene chloride. The chemical fractionation procedure will include a succession of solvent partitioning, absorption chromatography, HPLC using gel exclusion, and GC-MS. Initial phases of fractionation will follow closely the procedures outlined by MacLeod et al. (1985) for separation and analysis of petroleum compounds, but additional steps will be required for separation and characterization of the more polar fractions.

Interstitial water samples should also be examined. Because of uncertainties about the flux of interstitial water in oiled beaches and the resultant levels of polar metabolites, however, it is very difficult to estimate the volume of sample that may be required for characterization and quantification of polar metabolites. For initial trials, it is suggested that "interstitial water" be pumped or siphoned from a shallow "well" (i.e., a glass tube inserted to a depth of about 30 cm in heavily oiled beach sediments) into precleaned glass carboys (18-20 liters) containing acid and methylene chloride to carry out the initial extraction and to ensure preservation of the samples. An alternative collection technique would be to allow "interstitial water" merely to seep into an excavation on the beach and then to dip the water into the sample carboys. At each of the sites where sediments are collected for analysis, 100 liters of "interstitial water" should be collected. Exhaustive extraction with methylene chloride would be followed by analytical steps similar to those used for sediments.

Target compounds of the fractionation and analytical scheme will include phenolic, carbonyl, quinone, and carboxylic derivatives of polynuclear aromatic hydrocarbons, for example: 9-fluorenone, 9-fluorenone carboxylic acids, phenanthraquinone as potential derivatives of phenanthrene. Analogs related to naphthalene, anthracene, chrysenes, benzanthracene, pyrene, and benzpyrene will also be sought specifically, as will oxidation products of dibenzothiophenes. GC-MS data will be analyzed also for other major constituents in associated polar fractions to provide a general characterization of the polar compounds found in these samples.

C. Toxicity of Oxidized Petroleum Fractions

Following the initial characterization and quantification of polar constituents in oiled sediments and interstitial water, the fractionation process will be scaled up to provide quantities of material suitable for toxicity testing. Based on the results of initial fractionation and chemical characterization, selected polar fractions will be assayed for toxicity using the standard Microtox bioassay with organic extracts (Schiewe et al. 1985). Toxicity of polar fractions will be compared with the better known toxicities of aromatic fractions and reference compounds. The composition of all assayed fractions will be checked by GC-MS for consistency with previous fractionations of earlier samples.

D. Mass Balance Budget for Fate of Spilled Oil (Budget)

This task is primarily a synthesis function. Information on the distribution and fates of EXXON VALDEZ oil needs to be assembled from a number of sources and interpreted in light of existing information and models.

The following compartments and processes are proposed for initial analysis and inclusion in the Budget. Potential sources of data, historical information, and modeling expertise are also noted:

1. Floating oil (Distribution in Time & Space)
2. Evaporation
3. Photooxidation in the atmosphere
4. Mousse formation
5. Beaching of oil & mousse (T&S)
6. Water column accommodation (T&S)
7. Photooxidation in water column, in slicks and on beaches
8. Biodegradation in water column
9. Transport to subtidal sediments
10. Biodegradation in sediments

Representatives of the above noted activities, along with other recognized experts on oil weathering and fates, will be consulted for recommendations on appropriate approaches to synthesis, and for their judgments on the suitability and adequacy of existing information for development of the Budget. Apart from the information on polar constituents described above, no original data is proposed for collection under this project. Timely progress on the Budget will depend on the availability of suitable information from other sources and projects; chemical data, i.e., from T/S 1, will be of utmost importance to the completion of this project. Where existing information is found to be deficient, means will be explored for gathering of improved information. The reliability of all estimates will be assessed and qualified in the final analysis.

E. Quality Assurance and Control

All samples will be taken with careful adherence to QA/QC Plan for NRDA.

BIBLIOGRAPHY

Ahokas, J.T., H. Saarni, D.W. Nebert, and O. Pelkonen. 1979. The in vitro metabolism and covalent binding of benzo(a)pyrene to DNA catalyzed by trout liver microsomes. Chem. Biol. Interact. 25:103-111.

Brown, D.A., R.W. Gossett, and S.R. McHugh. 1987. Oxygenated metabolites of DDT and PCBs in marine sediments and organisms. PP. 61-69. In: J.M. Capuzzo and D.R. Kester (eds). Oceanic Processes in Marine Pollution. Vol. 1. Biological Processes and Wastes in the Ocean. Krieger Publishing Co., Malabar, Florida.

Cabioch, L., J.-C. Dauvin, C. Retiere, V. Rivain, and D. Archambault. 1982, Les effets des hydrocarbures de l'AMOCO

CADIZ sur les peuplements benthiques des Baies de Morlaix et de Lannion d'Avril 1978 a Mars 1981. PP. 205-228. In: Ecological Study of the Amoco Cadiz Oil Spill. Rpt of the NOAA-CNEXO Joint Scientific Commission. U.S. Dept. Commerce, NOAA. Washington, D.C.

Clark, R.C., and D.W. Brown. 1977. Petroleum: Properties and analyses in biotic and abiotic systems. PP. 1-89. In: D.C. Malins (ed.) Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Vol. I, Biological Effects, Academic Press, New York.

Dunn, B.P. 1980. Polycyclic aromatic hydrocarbons in marine sediments, bivalves, and seaweeds: Analysis by high-pressure liquid chromatography. PP. 367-377. In: A. Bjorseth and A.J. Dennis (eds.) Proc. 4th Internatl. Sympos. on Polynuclear Aromatic Hydrocarbons. Battelle Press, Columbus, Ohio.

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.

Jordan, R.R., and J.R. Payne. 1980. Fate and Weathering of Petroleum Spills in the Marine Environment: A Literature Review and Synopsis. Ann Arbor Science Publishers. Ann Arbor, Michigan. 174 pp.

Karickhoff, S.W. 1981. Semi-empirical estimation of sorption of hydrophobic pollutants on natural sediments and soils. Chemosphere 10:833-846.

Krone, C.A., D.G. Burrows, D.W. Brown, P.A. Robisch, A.J. Friedman, and D.C. Malins. 1986. Nitrogen-containing aromatic compounds in sediments from a polluted harbor in Puget Sound. Environ. Sci. Technol. 20:1144-1150.

Lech, J.J. and J.R. Bend. 1980. The relationship between biotransformation and the toxicity and fate of xenobiotic chemicals in fish. Environ. Health Perspectives 35:115.

Mackay, D. 1981. Fate and behaviour of oil spills. PP. 7-27. In: J.B.Sprague, J.H. Vandermeulen, and P.G. Wells (eds.) Oil Dispersants in Canadian Seas-Research Appraisal and Recommendations. Environment Canada, Toronto.

MacLeod, W.D., Jr., D.W. Brown, A.S. Friedman, D.G. Burrows, O. Maynes, R. Pearce, C.A. Wigren, and R.G. Bogar. 1985. Standard analytical procedures of the NOAA National Analytical Facility, 1982-1986: Extractable toxic organic compounds. 2nd Edition. NOAA Technical Memorandum NMFS F/NWC-92. 121 pp.

Means, J.C., J.J. Hassett, S.G. Wood, and W.L. Banwart. 1979. Sorption properties of energy-related pollutants and sediments. PP. 327- . In: P.W. Jones and P. Leber (eds.) Polynuclear Aromatic Hydrocarbons. Ann Arbor Science Publishers, Ann Arbor, Michigan.

Means, J.C., S.G. Wood, J.J. Hassett, and W.L. Banwart. 1980. Sorption of polynuclear aromatic hydrocarbons by sediments and soils. Environ. Sci. Technol. 14: 1524-1528.

Melancon, M.J.,Jr., and J.J. Lech. 1979. Uptake, biotransformation, disposition, and elimination of 2-methylnaphthalene and naphthalene in several fish species. PP. 5-22. In: L.L. Marking and R.A. Kimerle (eds.) Aquatic Toxicology. ASTM STP667. Am. Soc. Testing and Materials. Philadelphia, Pennsylvania.

Moore, S.F. and R.L. Dwyer. 1975. Effects of oil on marine organisms: A critical assessment of published data. Water Research 8: 819- .

National Academy of Sciences. 1985. Oil in the Sea. Inputs, Fates, and Effects. National Academy Press, Washington, D.C.

Neff, J.M., J.W. Anderson, B.A. Cox, R.B. Laughlin, Jr., S.S. Rossi, and H.E. Tatum. 1976. Effects of petroleum on survival, respiration and growth of marine animals. PP 516-539. In: Sources, Effects & Sinks of Hydrocarbons in the Aquatic Environment. The American Institute of Biological Sciences, Washington, D.C.

Overton, E.B., J.R. Patel, and J.L. Laseter. 1979. Chemical characterization of mousse and selected environmental samples from the AMOCO CADIZ oil spill. PP. 169-174. In: Proceedings, 1979 Oil Spill Conference (Prevention, Behavior, Control, Cleanup), American Petroleum Institute Publication No. 4308, Washington, D.C.

Overton, E.B., J.L. Laseter, W. Mascarella, C. Rashke, I. Noiry, and J.W. Farrington. 1980. Photochemical oxidation of IXTOC-I oil. PP. 341-383. In: Proc. Sympos. Preliminary Results from the September 1979 RESEARCHER/PIERCE IXTOX-I Cruise. NOAA Office of Marine Pollution Assessment, Boulder, Colorado.

Rice, S.D., A. Moles, J.F. Karinen, S. Korn, M.G. Karls, 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, 1970-1981. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS/NWC-67. 128 pp.

Roubal, W.T., T.K. Collier, and D.C. Malins. 1977. Accumulation and metabolism of carbon-14 labeled benzene, naphthalene, and anthracene by young coho salmon (Oncorhynchus kisutch). Arch. Environ. Contam. Toxicol. 5:513-529.

Schiewe, M.H., E.G. Hawk, D.I. Actor, and M.M. Krahn 1985. Use of a bacterial bioluminescence assay to assess toxicity of contaminated marine sediments. Canadian Journal of Fisheries and Aquatic Sciences 42: 1244-1248.

Varanasi, U., and J.E. Stein. 1990. Disposition of xenobiotic chemicals and metabolites in marine organisms. Environmental Health Perspectives (in press).

Varanasi, U., D.J. Gmur, and W.L. Reichert. 1981. Effect of environmental temperature on naphthalene metabolism by juvenile starry flounder (Platichthys stellatus) and rock sole (Lepidopsetta bilineata). Arch. Environ. Contam.Toxicol. 10:203-214.

Veith, D.G., D.L. Defoe, and B.V. Bergstedt. 1979. Measuring and estimating the bioconcentration factor of chemicals in fish. J. Fish. Res. Board Canada 36:1040- .

Wolfe, D.A. 1985. Fossil Fuels: Transportation and marine pollution. Chapter 2. pp. 45-93. In: Iver W.Duedall, Dana R. Kester, P. Kilho Park and Bostwick H. Ketchum (eds.), Wastes in the Ocean, Volume 4. Energy Wastes in the Ocean. John Wiley & Sons, New York.

Wolfe, Douglas A. 1987. Interactions of spilled oil with suspended materials and sediments in aquatic systems. pp. 299-316. In: K.L. Dickson, A.W. Maki, and W.A. Brungs (eds.), Fate and Effects of Sediment-bound Chemicals in Aquatic Systems. Proceedings of the 6th Pellston Workshop, August 12-17, 1984. Florissant, Colorado. Pergamon Press, Oxford, England.

Wolfe, D.A., R.C. Clark, Jr., C.A. Foster, J.W. Hawkes, and W.D. MacLeod, Jr. 1981. Hydrocarbon accumulation and histopathology in bivalve molluscs transplanted to the Baie de Morlaix and the Rade de Brest. PP. 599-616. In: AMOCO CADIZ. Internatl. Symposium on the Amoco Cadiz: Fate and Effects of the Oil Spill. Brest, France. 19-22 Nov 1979. CNEXO, Paris, France.

BUDGET: NOAA

Salaries	$60.0
Travel/Shipping	67.0
Contracts	580.0
Supplies	13.0
Equipment	0.0
Ship Costs	150.0
Total	$870.0

FISH/SHELLFISH INJURY ASSESSMENT

The grounding of the tanker Exxon Valdez discharged crude oil into one of the richest marine fisheries communities of the United States. Although oil contamination was most severe within PWS, the oil spread into large portions of the Gulf of Alaska (GOA), Lower Cook Inlet (LCI), Shelikof Strait, and other North Pacific Ocean waters off the coasts of Kodiak and the Alaska Peninsula. The fish and shellfish populations inhabiting these marine and estuarine waters form integral parts of a vast and complex ecosystem which also includes various other invertebrate species, birds, and mammals (including humans).

For example, the various life history stages of Pacific herring are important forage species for various piscivorous fishes (e.g. Pacific salmon, halibut, etc.), birds (gulls, cormorants, eagles, loons, etc.), mammals (sea lions, seals, whales, etc.), invertebrates (crabs), and are used for subsistence and commercial purposes. Regarding Pacific salmon, outmigrating smolts are important seasonal prey items for a variety of predatory fish and marine birds. Maturing salmon in the high seas and adult salmon returning to inland waters are the major portion of the diet of marine mammals such as sea lions, seals, and killer whales. Salmon are also the summer mainstay for eagles and many species of gulls. Spawning adults in the streams constitute almost 100% of the summer diet for bear and some land otter and are a very important link between the marine and terrestrial ecosystems. Salmon carcasses in streams, estuaries, and lakes are a crucial source of nutrients for planktonic communities and benthic organisms which represent the bottom rungs of the food chain for a wide variety of animals.

Various fish and shellfish species are also important components of human subsistence, commercial and sport fishery harvests. Communities such as Tatitlek, Chenega Bay, and English Bay depend upon subsistence fisheries in PWS and LCI for the very existence of their residents. The ex-vessel value of commercial fish and shellfish catches within PWS and other affected areas was estimated to be $1.3 billion in 1988. The largest recreational fisheries in Alaska for salmon, halibut, and rockfish center in Homer and Seward; a total of 300,000 angler days was recorded from these areas in 1987. Finally, many non-consumptive users of fish and wildlife also utilize the waters affected by the oil spill. Injury to fish and shellfish populations and resulting alterations to ecological communities would certainly diminish the value of the area to this group of people.

Bioassays prior to EVOS using crude oil from Prudhoe Bay and other areas have shown that exposure to concentrations as low as a few parts per billion in seawater will cause loss of limbs in Tanner crab, immediate death of eggs and larvae of herring, and death of Dungeness crab and various shrimp species. To assess the type and extent of injury done to marine fish and shellfish communities by the EVOS, a series of Fish/Shellfish (F/S) studies was developed by investigators from various State and Federal agencies. Species were selected for study based on their value as indicators of damage, their role as key species within the ecosystem, or their direct importance to man as components of subsistence, commercial or sport harvests.

Comparisons of the abundance of larvae, juveniles, or adults between oiled and non-oiled waters were chosen as the basic experimental units. In some studies, oiled and non-oiled waters pertain to different geographic areas; in other studies these terms relate to the same area or populations before and after the oil spill; in the remaining studies these terms refer to different areas and populations before and after the spill. Contamination of individual fish and shellfish will be documented by analysis of tissue samples, bile samples, and/or testing for induction of specific enzymes associated with hydrocarbon exposure. Damages to fish and shellfish populations resulting from the oil spill may be expressed as lethal (e.g., mortality to specific life history stages) or sublethal (e.g., decreased growth, reproduction potential, etc.) injuries. Such injuries to populations could cause losses in harvests and use of these species by man, and result in undesirable alterations of natural communities which might be difficult to restore.

Project proposals were reviewed and modified through input provided by State and Federal agency staff members, State and Federal attorneys, various experts retained by the State and Federal governments, and many corporate and private individuals. Based on these inputs and results from first year studies, a number of changes were made for the 1990 fisheries program. Salmon studies F/S 1, 2, 3, 4, 7, and 8 were continued, as modified, another year while F/S 9 (Early Marine Studies Outside PWS) which could not be initiated in 1989 was not approved for 1990. Dolly Varden and cutthroat trout study F/S 5 which was conducted in 1989 was approved for continuation, as modified, in 1990. The sport fish harvest and effort study (F/S 6) conducted in 1989 was not approved for continuation in 1990. A study on Dolly Varden and sockeye salmon in LCI (F/S 10) which was approved for 1989 but could not be implemented was not approved for 1990. The herring study (F/S 11) was expanded and modified considerably from that of 1989 and approved for continuation in 1990. Herring studies outside PWS (F/S 12) were completed in 1989 and not proposed for continuation in 1990. Clam study F/S 13 was combined with F/S 21 and approved for continuation, as modified, in 1990. The crab study within PWS (F/S 14) conducted in 1989 was not approved for continuation in 1990. The crab study outside PWS (F/S 22) was conducted in 1989 and was approved for continuation in 1990. The spot shrimp study (F/S 15) was conducted in 1989 and was approved for continuation in 1990 with few modifications. The rockfish studies F/S 17 and 23 were combined and modified for continuation in 1990. Multi-species trawl surveys, F/S 18 and 24 were conducted in 1989 and modified considerably for continuation in 1990. The oyster study (F/S 16), larval fish study (F/S 19), underwater observations (F/S 20), scallop mariculture study (F/S 25), and the sea urchin study (F/S 26) were not approved for continuation in 1990. Three new studies not conducted in 1989 were approved for implementation in 1990, these being sockeye salmon over-escapement (F/S 27), salmon run reconstruction (F/S 28), and salmon data base management (F/S 30).

FISH/SHELLFISH STUDY NUMBER 1

Study Title: Injury to Salmon Spawning Areas in PWS

Lead Agency: ADF&G

INTRODUCTION

Wild stock production of pink salmon in PWS has ranged from 10 to 15 million fish in recent years. Chum salmon returns have ranged from 800,000 to 1,500,000. Much of the spawning for pink and chum salmon (up to 75% in some years) occurs in intertidal areas. Intertidal spawning areas are susceptible to marine contaminants and the March 24, 1989, EVOS may adversely affect spawner distribution and success in Prince William Sound. To detect injury to pink and chum salmon stocks, intertidal contamination will be documented and correlated with trends in adult returns. Return estimates are based on accurate appraisals of catch and escapements. This project is designed to document oil contamination of intertidal spawning habitat; provide accurate estimates of escapements of wild stocks; and provide estimates of the intertidal and upstream area available for spawning. F/S Study 3 provides estimates of the wild stock component of the commercial catch. Results from F/S Study 3 and this study will be combined to estimate total return of wild stocks. F/S Study 2 estimates eggs and fry per square meter and egg to fry survival by tide zone in a subset of the streams in this study. Egg and fry density and survival data from F/S Study 2 will be combined with stream bed area estimates by tide zone from this study to estimate total egg deposition and egg to fry survival by tide zone in 138 streams.

The ADF&G has performed spawning ground surveys of the major salmon spawning streams in PWS since the late 1950's. An aerial survey program provides weekly estimates of numbers of fish in 218 spawning streams and a ground survey program on a subset of approximately 116 has provided corresponding estimates of numbers during the peak of spawning. During 1987 and 1988, funding for the ground survey program was severely curtailed and only 58 streams were walked. This study includes a thorough and extensive ground escapement survey program on salmon spawning streams for which there are past ground survey data and includes additional oiled and unoiled streams in western PWS. The study also includes ground surveys of salmon streams to document the presence of oil in intertidal spawning habitat.

In 1989 a total of 411 streams were surveyed for the presence of oil in intertidal spawning areas and 138 streams were included in the ground census of pink and chum salmon escapements. In 1990 the oil survey will be limited to the 138 streams in the escapement censuring portion of the project. The total area of intertidal and upstream spawning habitat will be estimated for each stream. Estimates of stream residence time (stream life) will be made for pink and chum salmon in 11 of the 138 streams.

The results of the study will provide accurate estimates of the pink and chum salmon escapement to each stream surveyed; will be correlated with escapement estimates based on aerial counts to estimate past and current year escapements for 218 streams included in the ADF&G aerial survey program; will provide estimates of post oil spill distribution of spawning within stream zones and among streams; will estimate total available intertidal and upstream spawning habitat for each stream; will estimate the average stream life for pink and chum salmon in PWS; and will provide an atlas of aerial photographs and detailed maps for important spawning sites.

OBJECTIVES

A. Determine the presence or absence of oil on intertidal habitat used by spawning salmon through visual observation, aerial photography, and hydrocarbon analysis of tissue samples from intertidal mussels at stream mouth.

B. Document the physical extent of oil distribution on intertidal spawning areas.

C. Estimate the number of spawning salmon, by species, within standardized intertidal and upstream zones for 138 streams in PWS.

D. Enumerate the total intertidal and upstream escapement of pink and chum salmon through weirs installed on one or more moderately large streams which are representative of streams in the aerial and ground escapement survey programs.

E. Estimate the accuracy of aerial counts for the 218 aerial index streams by comparison of paired ground and aerial counts from 138 of the streams on the same or adjacent survey dates and by comparison of aerial, ground, and weir counts on one stream.

F. Estimate the average stream life of pink and chum salmon in at least 11 streams in PWS using a variety of techniques.

G. Estimate 1961 through 1988 pink and chum salmon escapements to the 218 aerial index streams using the average observed error in the aerial survey method and on stream life data from 1989 and 1990.

H. Estimate the stream area available for spawning within standardized intertidal and upstream zones for the 138 streams surveyed.

I. Produce a catalog of aerial photographs and detailed maps of spawner distribution for the more important pink and chum salmon streams of Prince William Sound for use in designing sampling transects in the egg deposition and pre-emergent fry studies.

J. Identify streams appropriate for enumerating and CWT pink salmon fry.

METHODS

This project is an integral part of the study of impacts of the EVOS on Pacific salmon populations in PWS. Streams examined by this project are a subset of the anadromous salmon streams monitored by the ongoing ADF&G aerial survey program. Two additional F/S studies in PWS, pink and chum salmon egg deposition and pre-emergent fry studies Study 2 and salmon coded-wire tagging studies Study 3, will rely on information about salmon spawning and distribution obtained from this project.

Three crews of two people each will perform foot surveys of intertidal and upstream portions of 138 major pink and chum salmon spawning streams. Each stream will be visited once prior to the salmon returns to measure and mark tide levels and survey intertidal areas in and adjacent to the stream for presence of oil. Live and dead pink and chum salmon will be enumerated by ground survey crews in standardized intertidal and upstream zones in each stream. Streams will be enumerated three times at approximately two week intervals during the spawning season.

Streams to be surveyed will be selected according to the following criteria:

1. Stream is included in the ADF&G aerial survey program.
2. Stream is included in the pink and chum salmon egg deposition and pre-emergent fry project (F/S Study 2).
3. Stream was enumerated in prior spawning ground foot survey programs.
4. Stream is representative of the early, middle, and late run pink and chum salmon stocks in PWS.
5. Stream is representative of the spatial distribution of pink and chum salmon stocks in PWS and include streams from oiled and unoiled areas.

Maps of all streams in the program prepared from aerial photographs prior to the 1989 field season and modified and corrected during the three survey circuits in 1989 will be used and updated during the 1990 field season.

The pre-season survey to mark tide zones and document the presence of oil in the intertidal area at the stream mouth will be conducted in June, prior to the return of the pink and chum salmon. The location of tide levels 1.8, 2.4, 3.0, and 3.7 m above mean low water will be measured from sea level using a surveyors's level and stadia rod. Sea level at each site will be referenced to mean low water with site specific, computer generated tide tables which predict tides at five minute intervals. Tide zone boundaries will be delineated with color coded steel stakes. The linear length of the stream within each intertidal zone will be measured with a surveyors chain or range finder. The linear length of the stream in the upstream zone will be measured similarly on short streams and estimated from accurately scaled aerial photos on long streams. The average stream width will be determined from systematic width measurements taken in each zone. The number of intervals in each zone will depend on the length of the zone. Each measurement will be recorded at the appropriate location on the stream maps prepared in 1989.

Crews marking, measuring, and mapping tide zones will also conduct foot surveys of the intertidal stream bed and adjacent beaches to document, map, and classify any oil present.

During the escapement enumeration portion of the project, streams will be surveyed visually from the ground in a systematic order. During each stream survey the following data will be recorded:

- anadromous stream number and name (if available);
- latitude and longitude of the stream mouth;
- date and time (24 hour military time);
- tide stage;
- observer names;
- counts of live and dead salmon by species and tide zone (0.0-1.8 m, 1.8-2.4 m, 2.4-3.0 m, and 3.0-3.7 m above mean low water and upstream); and
- weather and comments on visibility, lighting, and other survey conditions.

All data will be recorded on pre-printed mylar data sheets which will overlay a map of the stream. Maps will be improved and modified during the survey to show spawner distribution within each zone and the upstream limit of spawning. Particular attention will be given to spawner density and distribution observations for the 48 streams to be sampled during F/S Study 2.

During the first survey circuit, a composite sample of mussels will be collected at the mouth of each stream for hydrocarbon analyses. Results of the analyses will be used to document the level of oil impact that the stream sustained. Each sample will consist of enough mussels to provide 10 grams of tissue (approximately 30 mussels) for analysis. The mussels will be collected in the zone from 0-2 m above mean low water in the immediate vicinity of each stream mouth and will be collected above water to avoid contamination by hydrocarbons on the water surface. The samples from each stream will be stored in separate, properly cleaned, glass jars with teflon lined lids. Appropriate chain of custody forms will accompany each sample.

During all three circuits counts of live and dead salmon will be made for the five tide zones (the intertidal zones < 1.8 m, 1.8-2.4 m, 2.4-3.0 m, 3.0-3.7 m above mean low water and the upstream zone) from the 1.8 m tide level to the limit of upstream spawning on all 138 streams. Tide stage will be monitored continuously and survey times and direction will be adjusted accordingly. If the tide stage at the time of the walk is at or below the 1.8 m level the stream walk will begin at the mouth of the stream and progress upstream. The mouth or downstream limit of the stream will be defined as the point where a clearly recognizable stream channel disappears or is submerged by salt water. Fish seen below the downstream limit will be included in an estimate of fish off the stream mouth and noted as a comment on the data form. If the intertidal portions of the stream above the 1.8 m level are submerged at the time the walk begins, the crew will proceed to the upstream limit of the walk, walk downstream, and coincide the end of the walk with the time predicted for the tide to be at or below the 1.8 m level. The upstream limit of a walk will be determined by the presence of natural barriers to fish passage (i.e. waterfalls), by the end of the stream, or by the upstream limit of spawning. The upstream limit of spawning will be marked on U.S. Geological Survey color aerial photos of each stream following each survey.

For counts of live and dead fish on moderate size streams with a single channel, crew members will walk together but independently count live fish in each intertidal zone. Crew members will individually enter their count on mechanical hand tallies. A maximum of three replicate counts may be made in each zone at the request of either observer. If the two counts differ by more than 10%, the zone will be recounted until counts differ by 10% or less. Upstream counts in a single channel will be similarly conducted at convenient stopping points (i.e., log jams or other clear counting delineators). To avoid confusion with counts of live fish, counts of dead fish will be recorded on the return leg of the stream walk. For large braided or branched streams, each crew member will count separate channels or upstream forks. To avoid perpetuating counting biases within a counting crew, personnel will be rotated between crews daily. When possible, crew members will not be assigned to the same streams on succeeding survey circuits.

Tests for variability among observers and among counting crews (observer pairs) will be conducted on 10 streams during each of the three enumeration survey circuits. At test streams, all observers will estimate numbers of live and dead pink salmon by zone and will record their counts independently. Counts will be compared after all test streams have been surveyed. Three crews of randomly paired observers will also replicate counts on 10 stream and results among observed pairs will be compared.

At 11 of the 138 streams in the ground survey program, fish will be include in a stream life study. Stream life studies will be modeled in part after previous studies in PWS (Helle et al. 1964; McCurdy 1984). For each stream will be captured at the stream mouths with beach seines and tagged with individually numbered Peterson disk tags color coded for day of capture. Tagging will be conducted at weekly intervals at each stream and during each tagging episode, 80 fish will be tagged. If fewer than 80 fish are available, all fish captured will be tagged. Daily counts of live and dead pink and chum salmon will be made by tide zone in each of the 11 streams. Live and dead fish bearing tags will be enumerated separately by color code and tag number. Only fish that have died since the previous count will be tallied in the daily surveys. To prevent duplicate counts between surveys, tails and tags of all dead pink and chum salmon observed will be removed.

At least one moderately large stream from among the 138 surveyed will be weired. The weir will be installed at the six foot tide level or the lower level of intertidal spawning. Weir crews will be record daily passage through the weir and will tag a portion of each day's escapement. Tags will be numbered sequentially and unique color codes will be used for each weekly interval. The weir crew will survey the intertidal and upstream portions of the stream daily for stream life data. Counts of live and dead pink and chum salmon will be made by tide zone. Fish bearing tags will be enumerated by color code and the sequential number on tags from dead fish will be recorded. Only fish that have died since the previous count will be tallied in the daily surveys. To prevent duplicate counts between surveys, tails and tags of all dead pink and chum salmon observed will be removed

Steams will be divided into categories based on levels of hydrocarbon contamination (as determined from visual observations species, stream zone, and stream for each will be assigned to one of the categories. Categorical data analysis techniques such as log linear models using chi-square statistics will be used to compare differences in spawning among streams and tide zones, and related these disruptions to the level of hydrocarbon contaminations. Count and spawner distribution data will also be compared with historical stream survey data and related to the level of hydrocarbon impact.

Steam life will be estimated using three methods. The first estimate is the mean difference between date of tag recovery from dead fish and the tagging date and the estimate will be made of the color coded tag lot to examine changes in stream life through times. The second estimate will use weir data and will be based on similar data for numeric tag codes from individual fish. The third method will be based on the difference in the dates between peak life count and the peak dead count.

BIBLIOGRAPHY

Helle, J.H., R.S. Williamson, and J.E. Baily. 1964. Intertidal ecology and life history of pink salmon at Olsen Creek, Prince William Sound, Alaska. U.S. Fish and Wildlife Service, Fisheries No. 483. Washington D.C.

McCurdy, M.L. 1984. Eshamy District pink salmon streamlife study, 1984. Alaska Department of Fish and Game, Division of Commercial Fisheries. Prince William Sound Data Report No. 94-18. Cordova

BUDGET: ADF&G

Salaries	$ 179.2
Travel	2.0
Contractual	145.3
Commodities	25.0
Equipment	40.0
Total	$ 391.5

FISH/SHELLFISH STUDY NUMBER 2

Study Title: Injury to Salmon Eggs and Pre-Emergent Fry in PWS

Lead Agency: ADF&G

INTRODUCTION

Much of the spawning for pink and chum salmon (up to 75% in some years) occurs in intertidal areas. Moles, Babcock, and Rice (1987) have shown the adverse effects of oil on pink salmon alevins, particularly in saltwater. The EVOS in PWS occurred immediately prior to emergence of pink and chum salmon from stream and intertidal spawning areas. Obviously, these areas have the potential to be severely impacted by the oil spill.

This study along with F/S Studies 1 and 3 support a comprehensive and integrated determination of injury to PWS salmon stocks. Results will include documentation of oil in intertidal salmon spawning habitat, pre-spill and post-spill estimates of total adult returns of wild and hatchery stocks, wild stock spawning success, wild stock egg to fry survival, and early marine survival of wild and hatchery stocks. Information on the extent and persistence of oil in the intertidal zone will be supplemented by Coastal Habitat Study 1. The results of F/S Studies 1 through 3 will be used by Economic Uses Study 3 to determine the extent of damage to the Prince William Sound salmon resource.

The ADF&G has sampled pink and chum salmon pre-emergent fry since the 1960's in order to predict the magnitude of future salmon returns. The fry dig program has operated at a reduced level since 1985. The oil spill has the potential to cause mortality to the critical egg and fry life stages and thus an increased and more comprehensive fry dig program is necessary. This project is designed to meet this need by assessing the effect of the oil spill on egg and fry of wild stock pink and chum salmon.

OBJECTIVES

1. Estimate the density of pink and chum salmon eggs (31 streams) and pre-emergent fry (48 streams) by tide zone in study streams.

2. Estimate over-winter mortality of pink and chum salmon eggs in oiled and control streams based on sampling of 31 natural streams.

3. Assess reductions in adult returns (if any) associated with increased egg to fry over-winter mortality in oiled streams.

4. Document hydrocarbon contamination using tissue concentrations of hydrocarbons in alevins and mussels, and mixed function oxidase (MFO) levels in alevins and eggs from study streams.

METHODS

There are approximately 900 anadromous fish streams in PWS. Pre-emergent fry sampling from some of these streams has historically provided an abundance index for pink salmon which is used to forecast future pink salmon returns. In recent years, 25 index systems considered representative of pink and chum salmon producing streams in PWS have been sampled during the fry dig program. Prior to 1985, sampling had been performed on as many as 45 streams. This study is designed to compare rates of mortality and abundance between areas with various levels of oil impacts and with data from sampling prior to the oil spill.

Sampling will consist of egg-digs performed in late September and early October, and pre-emergent fry digs conducted in mid-March to mid-April. Preliminary sampling was performed on two occasions during the spring of 1989 in an effort to assess fry abundance prior to and immediately after oil impact. On the first occasion the 25 streams in the ongoing ADF&G pre-emergent index program were sampled along with 14 additional streams. During the second event (approximately two weeks after the oil spill), 14 of the streams were resampled (representing both oiled and non-oiled areas) and an additional 16 streams were surveyed to assess their potential as egg and pre-emergent study streams. During September and October of 1989 egg digs were conducted on 31 of these streams.

Spring fry digs in 1990 will be conducted on 48 streams. These will include the 25 streams in the ongoing ADF&G pre-emergent index program plus 23 additional streams. The additional streams are located in Central to Southwest PWS where the majority of the oiling occurred. New study streams were selected using the following criteria:

- sufficiently large adult salmon returns to indicate a high probability of success in egg/fry digging;
- past history of egg/fry digging; and
- streams which had low to no oil impact in the immediate vicinity of high oil impact streams. This will help account for possible variability due to differing climatic/stream conditions.

The 48 streams span a range of oil impact and include streams in the historic sampling program. Most of the streams with suspected or obvious oil impact are new additions. The 30 streams in low impact areas include 27 with a history of sampling, six streams suspected of having received some impact including four with a history of sampling, and 12 streams with oil visibly present in the intertidal zone, including five with a history of sampling.

As in 1989, egg digs will be conducted in the fall on a subset of the 48 streams sampled for pre-emergent fry. Streams included in the fry sampling program, but not the egg sampling, are traditional fry sampling streams located on the eastern and northern shore of PWS. These streams are spatially quite distinct from the streams studied for oil impact effects. The 13 streams in low impact areas which were left in the egg dig program include four with a history of sampling. The streams suspected of having experienced some impact and the streams where impact is visibly obvious are the same as in the fry sampling program.

Sampling methods are identical for the pre-emergent fry and egg digs and are modeled in part after procedures described by Pirtle and McCurdy (1977). On each sample stream, four zones, three intertidal and one above tidal influence, will be identified and marked by crews conducting stream surveys under F/S Number 1 (PWS). The zones are 1.8-2.4 m, 2.4-3.0 m, 3.0-3.7 m above mean low water, and upstream of tidal influence. Separate linear transects 30.5 m in length will be established for the egg and pre-emergent fry digs in each zone (one transect for each type dig in each zone). The transects will run diagonally across the river with the downstream end located against one bank and the upstream end against the opposite bank. Overlapping of transects will be kept to a minimum to control the influence of fall egg digs on perceived abundance of fry during spring sampling. Fourteen circular digs (56 per stream), each 0.3 m^2, will be systematically dug along each transect using a high pressure hose to flush eggs and fry from the gravel. Eggs and fry will be caught in a specially designed net.

Numbers of live and dead fry by species as well as numbers of live and dead eggs by species will be collected from each 0.3 m^2 dig. Additional information such as date, time, zone, and a subjective estimate of overall percent absorption of the fry egg sacs in the sample will also be collected.

Tissue samples from pre-emergent pink salmon fry will be collected from the intertidal channels of streams. Tissue samples will be analyzed for the presence of hydrocarbons characteristic of those found in oil from the Exxon Valdez.

Fry sampled for hydrocarbon analysis will be from the intertidal stream bed at a level approximately 2.5 m above mean low water. Samples will be collected when the tide stage is below that level to avoid contamination from any surface film of oil on salt water. A shovel or clam rake will be used to dislodge the fry from the gravel and a stainless steel strainer which has been pre-rinsed in dimethylchloride and dried, will be used to catch the fry as they are swept downstream. Captured fry will be placed in jars with teflon lined lids and frozen.

Fry from each tide zone will be collected for MFO analysis and these samples will be selected systematically from the digs in each transect. Sampled fry will be preserved in buffered formalin solution in glass jars.

Pre-emergent fry/egg data will be summarized by date, stream, level of hydrocarbon impact, stream zone, and number of alive and dead, fry and eggs. A mixed effects analysis of covariance will be used to test for differences in egg to fry mortality due to oiling using the 31 streams sampled for both eggs and pre-emergent fry. Degree of oiling and height in the tidal zone will be treated as fixed effects. Height in the tide zone is nested within stream, a random effect. Possible covariates will be provided by hydrocarbon analysis of mussel populations in close proximity to each stream.

If no suitable hydrocarbon data are available, analysis of variance will be used. Degree of oiling as visually assessed by the mapping portion of the assessment of intertidal spawning areas will be used to post-stratify streams. Degree of oiling and height in the tidal zone will again be treated as fixed effects. Height in the tidal zone is nested within streams, a random effect.

Power of the test was estimated for the analysis of variance using data from the 1975 and 1976 egg and pre-emergent fry digs in PWS. This study indicated the ability to detect an increase of 15% (e.g. 10% mortality to 25% mortality) in egg to fry mortality at $\alpha = 0.05$, 95% of the time.

These studies will be used to test for 1) differences in egg to fry mortality between streams which were oiled and those that were not, and 2) increases in fry mortality in 1989 immediately after oiling.

Specific statistics to be estimated are:

- number of dead and viable eggs per square meter by salmon species, stream, and stream zone;
- number of dead and live fry per square meter by salmon species, stream, and stream zone; and
- egg to fry survival by salmon species, stream, and stream zone.

BIBLIOGRAPHY

Moles, A., M.M. Babcock, and S.D. Rice. 1987. Effects of oil exposure on pink salmon, O. gorbuscha, alevins in a simulated intertidal environment. Marine Environment Research, 21:49-58.

Pirtle, R.B. and M.L. McCurdy. 1977. Prince William Sound general districts 1976 pink and chum salmon aerial and ground escapement surveys and consequent brood year egg deposition and pre-emergent fry index programs. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 9, Juneau.

BUDGET: ADF&G

Salaries	$ 120.0
Travel	4.0
Contractual	150.0
Commodities	10.0
Equipment	18.8
Total	$ 302.8

FISH/SHELLFISH STUDY NUMBER 3

Study Title: Salmon Coded-Wire Tag Studies In PWS

Lead Agency: ADF&G

INTRODUCTION

Two questions must be answered to measure a loss in salmon production due to EVOS: 1) which stocks were exposed to contaminated waters and 2) to what extent did exposure reduce production (catch plus escapement)? This study will contribute to estimates of production and survival for hatchery and wild stocks in oiled and unoiled areas by quantifying fry outmigration, the adult component of the catch, and the escapement to hatcheries.

Wild stock returns of pink salmon in PWS have ranged from 10 to 15 million fish in recent years. Chum salmon returns have ranged from 800 thousand to 1,500,000. Additionally, returns of pink salmon to four PWS hatcheries now average more than 20 million fish and hatchery chum salmon returns in excess of 1.4 million fish are expected.

Catch and escapement data for wild pink salmon in PWS have been collected since 1961. In 1985, hatchery production became a significant part of the total salmon return. Consequently, pink salmon fry tagging was initiated at three area hatcheries in 1986 to estimate the survival of those stocks and their contribution to the 1987 catch. Similar estimates were made for a fourth facility based on tagging in 1987 and recoveries in 1988. F/S Study 3 estimated catch and survival rates of pink salmon released from these four PWS hatcheries based on tags applied in 1988 and recoveries of tags in the commercial, cost recovery and hatchery brood stocks in 1989. Tags were also applied to pink, chum, sockeye, coho, and chinook salmon releases from PWS area hatcheries and to smolts from two wild stocks of sockeye salmon. Tagging in 1990 will include all the same stocks plus one more wild stock of sockeye salmon and six pink salmon wild stocks. Tag recoveries are expected for releases at all four pink salmon hatcheries in 1989, releases of chum salmon from Main Bay Hatchery in 1986 and from Main Bay and Solomon Gulch Hatcheries in 1987, releases of sockeye salmon from the Main Bay facility in 1988, and releases of coho salmon from Wallace H. Noeremberg (WHN) and Solomon Gulch Hatcheries in 1989.

OBJECTIVES

1. Estimate catch, escapement, and survival rates of pink, chum, sockeye, coho, and chinook salmon released from five hatcheries in PWS. Outmigrating smolt and returning adults from these facilities are exposed to oil in varying degrees.

2. Estimate catch of the combined wild stocks of pink salmon in PWS and using escapement data from F/S Study 1, estimate differences in relative survival rates between pre- and post-spill brood years.

3. Estimate survival rates of wild pink salmon from three streams with contaminated estuaries and three with uncontaminated estuaries.

4. Provide marked salmon of known origin and oil exposure history for recovery by researchers studying early marine migration, growth, and survival (F/S Study 4).

5. Estimate survival rates of wild stocks of sockeye salmon, two from oiled areas, one from an unoiled area.

METHODS

A subsample of fry or smolt from all hatcheries releasing salmon into PWS will be tagged with a coded wire tag (Appendix A). Wild stock pink fry and sockeye smolt from both oiled and non-oiled areas of the Sound will also be tagged (Appendix B). Tags will be applied at rates which will insure that, given a realistic recovery effort, sufficient numbers can be recovered in the commercial fishery, hatchery cost recovery harvests, and hatchery brood stock collections (Appendixes) to allow researchers to estimate the contribution of each tag release group by district, week, and processor stratum. Release groups represent differences in release timing or treatment (i.e. fed vs. unfed fry)

Tag application will be similar among all hatcheries and among all wild stock systems. Fry or smolt will be randomly selected as they emerge from incubators or outmigrate from streams, anesthetized in a 1 ppm solution of MS-222, adipose fin clipped, and tagged. A random sample of 100 fish will be graded for fin clip quality each day. The proportion of bad clips in the sample will be used to discount the daily release of tagged fish. Clipped fish will be tagged and passed through a quality control device to test for tag retention. Fish repeatedly rejected will be killed to minimize the number of untagged but clipped fish in the release. Fish that retain tags will be held for 24 hours to determine short term mortality. A sample of tagged fish from each tagger will be taken each day and graded for tag placement according to criteria developed by Peltz and Miller (1988). Prior to release, a 200 fish sample will be randomly sampled to estimate overnight tag retention. The proportion of lost tags in the sample will be used to estimate tag retention in the daily release.

At the three Prince William Sound Aquaculture Corporation (PWSAC) hatcheries, tagged fish will be released directly into large saltwater rearing pens with untagged fish of the same release group. At the Valdez Fisheries Development Association (VFDA) Solomon Gulch Hatchery tagged fry will be placed in small enclosures within larger saltwater rearing pens for at least three days to allow them to recover from tagging before being mixed with unmarked fry from the same release group. At PWSAC hatcheries, unmarked fry entering large pens were counted with Northwest Marine Technology counters. At VFDA, unmarked fry in each pen will be estimated from counts of eggs in incubators minus egg mortalities. At all facilities, mortalities in the large pens will be estimated visually prior to release. Mortality rates based on visual estimates will be applied equally to tagged and untagged fish. The total number of fish in group t with valid tags at the time of release will be estimated as

$$T_t = (T_t - M_t) - (T_t - M_t)L_t,$$

where T_t = total number of fish tagged from group t,
M_t = overnight mortality among fish tagged from treatment group t,
L_t = overnight tag loss among fish tagged in treatment group t.

The VFDA estimate includes a term for short term mortality of tagged fish from treatment group t during saltwater rearing (S_t). The number of tagged fish released becomes

$$T_t = (T_t - M_t - S_t) - (T_t - M_t - S_t)L_t.$$

Hatcheries will release fry when plankton monitoring indices indicate peak zooplankton abundance.

Four hatcheries released 13 groups of pink salmon in 1989. Only one of these groups was not tagged. Each of the hatchery pink salmon tag groups contained tagged fish at the rate of approximately one tag per 570 fish released. The tag rate was held constant across release groups to prevent confusion of differential tag mortality with variation in survival between release groups (Peltz and Geiger, 1988; Geiger and Sharr, 1989). In 1989, chum salmon were tagged at the rate of approximately one tag per 60 fish released at the Solomon Gulch Hatchery near Valdez.

In 1990, hatchery pink and chum salmon tagging will continue at the same level of effort with the addition of chum salmon at the Esther Island Hatchery; approximately 250,000 of these chum salmon will be tagged in one release group.

Wild pink salmon will be tagged from six stocks examined in F/S Study 2. Fry will be captured as they emerge using various means. The fry will be anesthetized with MS-222 and tagged with Northwest Marine Technology tagging equipment and tags. The anesthesia and associated trauma will require that the tagged fish be held separate from their untagged cohorts, until they appear to have fully recovered from the effects of tagging. The extent to which the survival and behavior of the tagged fish can be extrapolated to other groups of salmon will be assessed at the time of recovery.

Prior to tagging, hatchery chinook and coho salmon smolt in hatcheries will be crowded using seines. A sample of smolt will be drawn from each rearing appliance in approximate proportion to the number of fish in that appliance. They will be anesthetized with MS-222, their adipose fin excised, and a tag applied using Northwest Marine Technology equipment and tags. A sample of fish from each day's tag production will be retained to estimate short-term tag loss and tag induced mortality. Following tagging, the tagged fish will be returned to mix with untagged cohorts. All mortalities during the first week after tagging will be examined and the tag status noted. At the end of a week, the fish will again be crowded, and a sample of approximately 2,000-4,000 fish from each rearing appliance will be drawn. These fish will be anesthetized, and run through a tag detector. Peterson abundance estimates for all rearing appliances will be performed and any major discrepancies from hatchery inventory records noted. Finally, a written description of the tagging will be developed. This will include a detailed description of each tag lot, the number of fish tagged, the total number of fish in the release lot, the average size of the fish at release, a profile of the exposure history of the release lot to the oil spill, and all information required by the ADF&G Coded-Wire Tag Laboratory which coordinated tagging in Alaska.

In 1989 wild sockeye salmon were tagged at Eshamy and Coghill Lakes. Smolt were captured in traps as they migrated to saltwater. The smolts were anesthetized with MS-222 and tagged with Northwest Marine Technology tagging equipment and tags. The anesthesia and associated trauma required that the tagged fish be held separate from their untagged cohorts until they appeared to have fully recovered from the effects of tagging. As in the wild pink salmon tagging, the extent to which the survival and behavior of the tagged fish can be extrapolated to other groups of salmon will be assessed at the time of recovery. The rate of tag occurrence in the stock will be determined from counts at an adult salmon weir in each of the systems. All fish passing through the weirs will be enumerated and heads from fish with adipose fin marks will be taken at the weir for tag removal and decoding. Hatchery produced sockeye salmon smolts will be tagged using the methods described for chinook salmon above.

The recovery samples are from a stratified sample (Cochran 1977), by district and discrete time segments. The recovery will be further stratified by processor as described in Peltz and Geiger (1988). For each time and area specific stratum, 15% of the pink salmon catch and a minimum of 20% of other salmon species catches will be scanned for fish with a missing adipose fin. Catch sampling will be done in four fish processing facilities in Cordova, one facility in Seward, and three facilities in Valdez. When feasible, sampling will occur at facilities in Kodiak, Kenai, Anchorage, and Whittier and on large floating processors. All deliveries by fish tenders to these facilities will be monitored by radio and by daily contact with processing plant dispatchers to ensure that the catch deliveries being sampled are district specific.

In addition to catch sampling at the processing facilities, approximately 15% of the fish in the hatchery terminal harvest areas will be scanned for fish missing adipose fins. There will be a brood stock tag recovery effort at each of the three hatchery facilities where tags were initially applied. A minimum of 50% of the daily brood stock requirements of each facility will be scanned for fish with missing adipose fins. Finally, there will be an intensive survey of adult pink salmon returning to natural systems where tagging was conducted, and a weir will be operated for sampling adult sockeye salmon on those systems where sockeye salmon were tagged.

In the catch, terminal harvest, brood stock, and natural system surveys, the total number of fish scanned and the total number of fish with missing adipose fin will be recorded. The heads will be removed from fish with missing adipose fins. Each head will be tagged with uniquely numbered strap tags. Recovered heads will be assembled and pre-processed in the Cordova area office. Heads will then be sent to the FRED Division Coded-Wire Tag Laboratory in Juneau for decoding and data posting.

A statewide coded-wire tag lab is located in Juneau and operated by FRED Division of ADF&G. Coded-wire tag sampling forms will be checked for accuracy and completeness. Sampling and biological data will first be entered onto the laboratory's data base. Next, the heads will be processed. This involves removing and decoding the tags, and entering the tag code and the code assigned in the recovery survey into the database. Samples will be processed within five working days of receipt.

The first step in the coded-wire tag analysis will be to estimate the harvest of salmon from each tag lot, in units of adult salmon. Adult salmon from these tagged lots will be recovered in the common property fishery, the hatchery cost recovery fishery, and the adult brood stock. For the hatchery stock, a modification of the methods described in an ADF&G technical report by Clark and Bernard (1987) will be used. The specific methods, estimators, and confidence interval estimators are described in ADF&G technical reports on two previous studies of pink salmon in PWS: Peltz and Geiger (1988), and Geiger and Sharr (1989). Additional references on methods of tagging pink salmon in PWS can be found in Peltz and Miller (1988). In the case of the wild stocks, the methods and estimators and necessary assumptions are described by Geiger (1988).

The contribution of a particular tag lot, to a particular fishery stratum, is estimated multiplying by the number of tags recovered in the structured recovery survey, by both the inverse of the proportion of the catch sampled (the inverse sampling rate), and by the inverse of the proportion of the tag lot that was actually tagged (the inverse tag rate). The escapement (brood stock) of each tag lot is estimated using methods unique to the particular situation. After the contribution to each fishery is estimated for the tag lot, the survival is estimated by summing the estimated harvest of the tag lot in each fishery, and the estimated escapement (brood stock), and dividing by the estimated number of fish represented by the tag code.

Total catches stratified by week, district, and processor were obtained from summaries of fish sales receipts (fish tickets) issued to each fisherman. The total hatchery contribution to the commercial and hatchery cost recovery harvest is the sum of the estimates of contributions in all week, district, and processor strata:

$$\hat{C}_t = \Sigma_i X_{ti} (N_i / S_i) p_t^{-1}$$

where:
$\hat{C}_t$ = catch of group $\underline{t}$ fish,
X_{ti} = number of group $\underline{t}$ tags recovered in $\underline{i}$th strata,
N_i = number of fish caught in $\underline{i}$th strata,
S_i = number of fish sampled in $\underline{i}$th strata,
p_t = proportion of group $\underline{t}$ tagged.

For sampled strata, we used a variance approximation which ignores covariance between release groups (Geiger 1988):

$$V(\hat{C}_t) = \Sigma_i X_{ti} (N_i/S_i p_t)^2 [1 - (N_i/S_i p_t)^{-1}].$$

The average tag recovery rate for all processors in a week and district will be used to estimate hatchery contribution in catches delivered to processors not sampled for that district and week. Variances associated with unsampled strata will not be calculated.

BIBLIOGRAPHY

Clark, J.E. and D.R. Bernard. 1987. A compound multivariate binomial hypergeometric distribution describing coded microwire tag recovery from commercial salmon catches in southeastern Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 261.

Cochran, W. G. 1977. Sampling Techniques, 3rd ed. John Wiley and Sons, New York, New York.

Geiger, H.J. 1988. Parametric bootstrap confidence intervals for estimates of fisheries contribution in salmon marking studies. Proceedings of the international symposium and educational workshop on fish-marking techniques. University of Washington Press, Seattle. In press.

Geiger, H.J. and S. Sharr. 1989. A tag study of pink salmon from the Solomon Gulch Hatchery in the Prince William Sound fishery, 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries. In press.

Peltz, L. and H.J. Geiger. 1988. A study of the effect of hatcheries on the 1987 pink salmon fishery in Prince William Sound, Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries. In press.

Peltz, L. and J. Miller. 1988. Performance of half-length coded-wire tags in a pink salmon hatchery marking program. Proceedings of the international symposium and educational workshop on fish-marking techniques. University of Washington Press, Seattle. In press.

BUDGET: ADF&G

Salaries	$ 902.0
Travel	21.0
Contracts	667.0
Supplies	100.0
Equipment	300.0
Total	$1,990.0

Appendix A. **Coded-wire tagging goals for hatchery releases of salmon in PWS, 1990.**

Hatchery	Species	Projected Release	Valid Tag Goal	Number Tags to Order	Total Release /Marked Ratio Goal	Number of Tag Codes	Number Tags \Code	Tag Length
Armin F. Koernig	Pink	120,000,000	200,000	255,000	600	8	30,000	Half
						1	15,000	Half
Cannery Creek	Pink	150,000,000	250,000	277,000	600	7	37,000	Half
						1	18,000	Half
Solomon Gulch	Pink	125,000,000	208,333	225,000	600	5	45,000	Half
Wally Norenburg	Pink	250,000,000	416,667	460,000	600	10	46,000	Half
GRAND TOTAL	Pink	645,000,000	1,075,000	1,217,000	600	32		Half
Solomon Gulch	Chum	6,000,000	40,000	40,000	150	1	30,000	Half
						1	10,000	Half
Wally Norenburg	Chum	50,000,000	100,000	100,000	500	4	25,000	Half
GRAND TOTAL	Chum	56,000,000	140,000	140,000	400	6		Half
Ft. Richardson								
Whittier	Coho	100,000	20,000	20,000	5	1	20,000	Full
Cordova	Coho	60,000	10,000	10,000	6	1	10,000	Full
Solomon Gulch	Coho	1,000,000	30,000	30,000	33	1	30,000	Full
Wally Norenburg	Coho	2,000,000	70,000	70,000	29	1	50,000	Full
GRAND TOTAL	Coho	3,160,000	130,000	130,000	24	5		Full
Main Bay	Sockeye	2,500,000	100,000	100,000	25	8	12,500	Order Filled
GRAND TOTAL	Sockeye	2,500,000	100,000	100,000	25	8	12,500	Order Filled
Wally Norenburg	King	150,000	30,000	30,000	5	1	30,000	Full
GRAND TOTAL	King	150,000	30,000	30,000	5	1	30,000	Full
GRAND TOTAL	ALL	706,810,000	1,475,000	1,617,000	479			

Appendix B. Coded-wire tagging goals for wild stock of salmon in PWS, 1990.

System	Treatment	Species	Projected Release	Valid Tag Goal	Total Release /Marked Ratio	Number of Tag Codes	Number of Tags \Code	Tag Length
Upper Herring B.	Oiled	Pink	1,000,000	40,000	25	2	25,000	Half
Hayden Ck.	Oiled	Pink	1,000,000	40,000	25	2	25,000	Half
Loomis Ck.	Oiled	Pink	1,000,000	40,000	25	2	25,000	Half
McClure Ck.	Clean	Pink	1,000,000	40,000	25	2	25,000	Half
O'Brien Ck.	Clean	Pink	1,000,000	40,000	25	2	25,000	Half
Totemoff Ck.	Clean	Pink	1,000,000	40,000	25	2	25,000	Half
GRAND TOTAL	All	Pink	6,000,000	240,000	25	12	300,000	Half
Coghill	Clean	Sockeye	1,000,000	20,000	50	1	20,000	Half
Eshamy	Oiled	Sockeye	1,000,000	20,000	50	1	20,000	Full
Jackpot	Oiled	Sockeye	200,000	20,000	10	1	20,000	Half
GRAND TOTAL	All	Sockeye	2,200,000	60,000	37	3	60,000	Both
GRAND TOTAL	All	All	8,200,000	300,000	27	15	360,000	Both

FISH/SHELLFISH STUDY NUMBER 4

Study Title: Early Marine Salmon Injury Assessment In PWS

Lead Agencies: ADF&G, NMFS

INTRODUCTION

The early marine period is a critical one for salmon because it is at this time that the greatest mortality is sustained (Parker 1968; Bax 1983, Hartt 1980; Foerster 1968; Ricker 1976; Nichelson 1986). Mortality is considered to be inversely proportional to the rate of growth, since a prolonged juvenile period will result in a prolonged vulnerability to predators (Parker 1971; Healey 1982; Taylor 1977; Walters et al. 1978). For a possible exception to this, see Helle (1980). Therefore, factors that lower normal growth rates during the early marine period, such as toxic effects of exposure to hydrocarbons, reduction in prey populations, or increased energy expenditures associated with the disruption of normal migratory patterns, could have a strong influence on survival.

Juvenile salmon are especially susceptible to oil toxicity when first in seawater (Rice et al. 1975; Rice et al. 1984). Sublethal levels of hydrocarbons can affect metabolism and reduce growth of juvenile salmon (Rice et al. 1975). Sublethal levels of water-soluble hydrocarbons can also damage olfactory lamellar surfaces, conceivably impacting migratory behavior and feeding patterns (Babcock 1985). Oil can also be toxic to littoral and pelagic macroinvertebrates (Caldwell et al. 1977; Gundlach et al. 1983). Thus, mortality, reduction of reproductive potential, or growth inhibition of prey populations could reduce growth rates of juvenile salmon, and thus increase their exposure to predation.

During the past decade, five world-class hatcheries have been established within PWS. These facilities, operated by the PWSAC and the State of Alaska, produced approximately 535 million juvenile salmon in 1989. The hatchery contribution represents roughly half of the total number of juvenile salmon produced in PWS this year. CWT program marked roughly 1.3 million juvenile salmon this year. Approximately one in every 1,000 juvenile salmon in PWS this year was expected to have a CWT. Recoveries of these marked fish in PWS will play a major role in our assessment of the impact of the oil spill.

In 1990, the impact assessment will be conducted by the ADF&G and the National Marine Fisheries Service (NMFS). Studies conducted by ADF&G will focus on the impact of the oil on growth and migratory behavior, and studies conducted by NMFS will focus on pairwise comparisons of salmonid growth and behavior in oiled and unoiled nearshore rearing habitats. Sampling will be coordinated to produce a single cohesive data base of 1) coded-wire tag recoveries and 2) zooplankton and epibenthos collections with associated temperature data.

This study emphasizes a coordinated approach to attaining the objectives. The studies are mainly complementary. A strong effort is required because of 1) the high ecological and economic value of the resource and 2) the wide range of habitats utilized by salmon during the early marine phase.

OBJECTIVES

A. Estimate the effects of oil contamination on abundance, growth, feeding habits, and behavior of juvenile salmon during their early marine residence.

B. Describe migration patterns of juvenile salmon relative to oiled and unoiled areas of western PWS.

C. Estimate hydrocarbon levels in tissues of juvenile salmon collected in oiled and unoiled areas in 1989.

D. Determine distribution, abundance, habitat utilization, size and growth, and feeding habits of juvenile pink and chum salmon, in order to compare these parameters with 1989 results.

E. Determine if sediment contamination has reduced the abundance of primary prey species of harpacticoid copepods.

F. Determine if pollution of azoic sediments with hydrocarbons will influence meiofauna colonization, especially harpacticoid copepods, in terms of species distribution and abundance.

PART I: Impacts of Oil Spill on Migratory Behavior and Growth

The present study is designed to distinguish between the effect of oil and other factors on growth and migration by resampling fry in a few areas examined in 1989. It is expected that the major difference between these areas in 1990 compared to 1989 will be a lower level of oil contamination. In 1990, the study will focus on tag lots that will have been released in a period of a week or less.

Portions of the 1989 sampling program will be discontinued in 1990 in order to focus attention on growth and migrations. Discontinued studies will include tow net sampling because of low yields, fry stomach analyses because growth can be determined by less expensive means, and epibenthic sampling.

OBJECTIVES

A. Compare the growth of CWT salmon captured in oiled and unoiled areas in 1989 with fry captured in the same areas in 1990. Determine at the alpha=.05 level whether size and condition factors are different in CWT fry collected in oiled and unoiled years.

B. Document the impact of oil on the migratory path and speed of migration of CWT salmon releases in PWS. Determine at the alpha=.05 level whether migration speeds and patterns are different in oiled and unoiled areas and in oiled and unoiled years.

C. Document the hydrocarbon content of CWT fry collected in 1989. Determine at the alpha=.05 level whether hydrocarbon content differs in CWT fry collected in oiled and unoiled areas in 1989.

METHODS

Fry collections will be targeted on tag lots that are released during a time of 1 week or less. Recovery of these salmon at later times and in different places will allow relatively accurate measurements of growth, and reasonable estimates of migration paths and migration speeds. Approximately 1.3 million tagged fish will be released. The goal will be to recover approximately 30 tagged fish in each of several tag lots each sampling time period. Based on 1989 recovery data, it is expected that during the proposed 6-week field season, sufficient fry should be collected to evaluate approximately six tag lots. The recovery effort will be targeted on tag lots released from Esther and Armin F. Koernig (AFK) hatcheries, because (1) a good data set is presently available on releases from these hatcheries in 1989, (2) the field crew knows where fry released from these hatcheries can be collected, and (3) the hatcheries are located in an unoiled area (Esther) and an oiled area (AFK).

Most collections, especially early in the season, will be made with a beach seine (modified Auke Bay design) and 18" diameter dip nets on two or three beaches in each sampling area. A 120 ft. purse seine (modified Auke Bay design) will be used in nearshore areas where the beach seine can not be used. Water temperatures and salinity will be measured with a salinometer at 0 m and 5 m. Tide levels and directions will be recorded for each sampling site.

To avoid excessive mortality when large numbers of fish are caught, fish will be placed in a holding tank until processing is completed. Lots of approximately 300 ml of fish (measured by displacement in a 1-liter beaker) will be put through a 2-inch tunnel tag detector (Northwest Marine Technologies) with a small stream of salt water. When a tag is found in the lot, the lot will be continuously divided until the tagged fish is found. One 300-ml sample of fry will be sorted immediately to determine species composition and released. Another sample of approximately 80 fry will be preserved in buffered formalin for later size measurements. This number should be sufficient to identify different size groups if they should occur. Remaining fry will be released.

All tagged fish will be blot-dried, and measured (snout to fork). Tags on these fish will be read later by the FRED Tag Lab. After reading the heads will be preserved in 70% ethanol and archived in case otolith analyses are desired at a later date. Chain of Custody procedures will be used throughout transfer and storage of these samples. Untagged fish will be left in buffered 10% formalin for at least 30 days to standardize shrinkage. These fry will be rinsed in buffered sea water, blot-dried, weighed and measured.

Analyses will test the null hypothesis of no difference between CWT pink salmon fry collected in oiled and unoiled areas at the alpha = 0.05 level. A Chi-square analysis will test the hypothesis of no difference in presence/absence of oil among the different sampling areas.

Analysis-of-variance of CWT fry will help separate the effects of oil from other variables contributing to variation in growth rates (change in body weight per unit time) and condition factor. Other variables include year, hatchery of origin, tag code lot, sampling time, and sampling area. Those variables contributing significantly to differences in growth and condition will be further analyzed to assess the relationship. Where applicable analyses will use tag code lot as a blocking variable to evaluate effects of oil. In addition, apparent growth rate curves will be analyzed using untagged fry caught at the same sample areas during the different sample times.

Migration rates will be calculated using the minimum distance between release and recovery sites and the average release date for a given tag lot. Differences in migration rate, distance and pattern will be analyzed with ANOVA as described in the above section.

PART II. Impact of Oil Spill on Juvenile Pink and Chum Salmon and Their Habitat

INTRODUCTION

In 1989, the NMFS component of the early marine salmon studies focused on pairwise comparisons between oiled and non-oiled study sites in PWS. The objectives were to determine if oil had affected distribution, abundance, size and nominal growth rates, feeding habits, and prey abundance.

Epibenthic harpacticoid copepods produced in the intertidal and upper subtidal reaches are an important food resource for juvenile pink and chum salmon (e.g., Kaczynski et al. 1973; Healey 1980; Godin 1981; Cooney et al. 1981; Landingham 1982; Cordell 1986; Taylor et al. 1987; Landingham and Mothershead 1988). The trophic link between the benthos and the salmon is the most likely route for an impact on juvenile salmon in 1990. The contamination of the littoral zone could reduce prey densities by direct toxicity to harpacticoid copepods (Bonsdorff 1981; Bodin 1988), or by changing harpacticoid species assemblages from those dominated by epibenthic species to those dominated by inbenthic species which are not as available to visual feeders (Stacey and Marcotte 1987). Uptake of hydrocarbons by harpacticoids living in and on the contaminated sediments could also reduce growth. Contamination from prey decreases growth and causes changes in feeding behavior of juvenile pink salmon (Schwartz 1985). Slower-growing juveniles are more susceptible to size selective predation (Parker 1971; Hargreaves and LaBrasseur 1985) and thus suffer higher mortality (Healey 1982; Taylor et al. 1987; Taylor 1988).

Proposed research for continuation in 1990 will collect data on distribution, abundance, habitat utilization, size and growth, and feeding habits of juvenile pink and chum salmon, in order to compare these parameters with the 1989 results. Resolution of growth comparisons between oiled and non-oiled locations will be increased by using otolith increment analysis (Volk et al. 1984). Research will determine if sediment contamination has reduced the abundance of primary prey species of harpacticoid copepods and will determine if pollution of azoic sediments with hydrocarbons will influence meiofauna colonization, especially harpacticoid copepods, in terms of species distribution and abundance.

OBJECTIVES

(Letters refer to general objectives described above, as well as three components listed above.)

D-1. Test, at alpha = 0.05, if the abundance of juvenile pink and chum salmon does not differ between oiled and non-oiled areas.

D-2. Compare distribution and habitat utilization by juvenile salmon between 1989 and 1990.

D-3. Test, at alpha = 0.05, if the size and growth rates of juvenile salmon do not differ between oiled and non-oiled areas; to compare growth rates between 1989 and 1990.

D-4. Quantify the feeding habits of juvenile pink and chum salmon in terms of fullness, frequency of occurrence, biomass, and Index of Relative Importance, and compare oiled and non-oiled areas in 1990 and between 1989 and 1990.

D-5. Determine migratory behavior of juvenile salmon based on coded-wire tag recoveries.

E-1. Examine if sediment contamination has reduced the abundance of primary prey species (harpacticoid copepods).

E-2. Test, at alpha = 0.05, if the abundance of epibenthic prey species for juvenile salmon does not differ between heavily contaminated and lightly contaminated beaches.

F-1. Test, at alpha = 0.05, if the colonization of sediments by harpacticoid copepods and other meiofauna is not affected by the presence of oil in the sediments.

METHODS

Sampling Design

Component 1 (Objective D)

In order to make direct comparisons between years, the same four oiled and four non-oiled locations sampled in 1989 in Western PWS will be sampled again in 1990. The locations are categorized as bays or migration corridors. At each location, three habitat types will be sampled. These habitat types are grossly characterized by grade and substrate: low gradient beach (<10% grade, granule-pebble substrate); medium gradient beach (12-25% grade, pebble-cobble substrate); and steep gradient beach (>50% grade, bedrock or large boulder substrate). Particular beaches will be selected for similarity between oiled and non-oiled areas in such characteristics as wave exposure, macrophyte coverage, and substrate. Two beaches of each habitat type will be sampled within each location in 1990, for a total of 48 sites. To minimize variability due to tide heights, sampling at the sites will be restricted to the -1 to +3 tide range. The sites will be sampled on each of four sampling cruises from mid-April to early June.

Component 2 (Objective E)

Abundance of important harpacticoid prey species will be compared between "lightly oiled" and "heavily oiled" beaches within each of three oiled embayments. Comparisons between oil contamination levels within an embayment was chosen to minimize the effects of geographic variability. Three 40 m transects at the 0 tide level will be established for each of the two contamination categories within each embayment. Random number series will be used to select 25 points along each transect for sampling with an epibenthic pump. Transects for prey abundance will be sampled during the low-tide series encompassed by sampling cruises 1,3, and 4; a different embayment will be sampled on each of these cruises.

Component 3. (Objective F)

Colonization by meiofauna of azoic sediments will be compared between oiled and control sediments. Standard dish pans with holes to allow water drainage will be filled with control, low oil (0.5%) and high oil (2.0%) azoic sediments. The pans will be aged in running freshwater for 1-2 weeks prior to use. Three pans for each level (control, two treatments) will be buried in the lower intertidal in two locations (a lightly oiled and a heavily oiled location). The pans will be placed parallel to the water line, approximately 5 pan widths apart. The sediments used in this experiment will be collected in Auke Bay, and made azoic by freezing. Approximately one-third will be used for the controls. The remaining sediments will be divided in half, and mixed with Prudhoe Bay crude oil to 0.5% and 2% concentrations. The pans will be placed in PWS in late April, and be sampled for meiofauna after 1 day and 4, 6, and 12 weeks.

Sample Collection

1. Fish Sampling

Fish sampling at study sites will be restricted to the -1 to +3 tide levels to minimize tidal effects between sites. Fish will be captured using 37 m beach seines. Catches will be sorted by species and enumerated; all salmon will be checked for the presence of CW tags using an OMNI coded-wire tag detector. Each CW tagged salmon will be measured, weighed and frozen. On each sampling trip, up to 60 each juvenile pink and 60 juvenile chum salmon from each sample site will be preserved in formalin for later length and weight measurements; 10 of each species of these fish will be randomly selected during processing for diet analysis. In addition, 50 juvenile pink salmon from each embayment site will be retained for otolith analysis, as per standard operating procedures. All other fish will be released.

As time permits, the shoreline within the general vicinity of the habitat sites will be surveyed, and additional seine sets made. Juvenile salmon collected in these sets will be enumerated, checked for coded-wire tags, and used to supplement collections for otolith and stomach analyses when insufficient numbers are collected at the regularly sampled beaches. All other fishes caught in such sets will also be identified and enumerated.

2. Zooplankton, Epibenthic Harpacticoids, and Meiofauna Sampling

In the offshore water adjacent to the habitats sampled, triplicate samples of pelagic zooplankton will be taken with a 20-m vertical haul of a 0.5 m diameter 243 micron net. Epibenthic harpacticoid copepods will be sampled using a pump sampler (Cordell and Simenstad 1989).

Meiofauna in the pan experiment (Component 3) will be sampled by taking five core samples from each pan, using 50-ml syringes. Samples will be fixed in buffered formalin in 120-ml glass jars and labeled and sealed in the same manner as the other prey samples.

3. Hydrocarbon Samples

Mussel samples and sediment samples will be taken for hydrocarbon analysis at each location. Mussels will be sampled at or near one of the habitats within each site, and frozen. Three replicate samples will be collected in 120 ml glass jars from the top 2 cm of sediments from 6-8 spots along the water line adjacent to the beach seine site. For the epibenthic transects, the replicate samples will be aggregated from within the six random quadrants selected for photographing. Two core samples will be taken for hydrocarbon analysis from the experimental sediment pans. A blank sample will be provided from each site. All sediment samples will be frozen.

4. Environmental Data

Water temperature and salinity at 0.5 m depth, wave height, and current measurements will be taken at each nearshore site regularly sampled, and at each prey transect. Water temperatures at 1 m and 4 m will be taken in association with each set of zooplankton tows. Temperature and salinity will be measured using a Beckman probe conductivity-temperature meter. Current will be measured with a Marsh-McBirney induction current meter. Wave height will be measured with a meter stick. Extent of oil deposition and of visible oil in the water will also be noted for each habitat. A recording temperature/salinity device will also be deployed at the two sites where pans of experimentally oiled and control sediments are placed, for hourly temperature records. The boundary of the oxic-anoxic layer within the sediment pans will be measured at the end of the experiment.

Sample Processing

1. Fish Samples

Coded-wire tagged fish will be stored frozen until processing for tags. The fish will be transported from field collection to the Auke Bay Laboratory, then to the ADFG Tag Processing Laboratory in Juneau. The tag lab personnel will decode the tags, and transmit the information to NMFS and to the ADFG investigator coordinating Early Marine Salmon Studies.

After being weighed and measured, each fish retained for stomach analysis will be put into a labeled 20-ml vial filled with 50% isopropyl alcohol or 70% ethanol. Subsequent analysis will involve excising and weighing the foregut, removing the contents and estimating stomach fullness, and reweighing the empty foregut to get a measure of total content wet weight. The prey items will be identified to a minimum of Order level and counted.

2. Otolith samples

The sagittal otoliths will be removed from frozen samples of at least 50 juvenile pink salmon from each of the four embayment locations, for both 1989 and 1990 samples. Each otolith sample will be assigned a sample number corresponding to the original sample and the fork length of the individual fish. The otoliths will be sent to a qualified contractor, who will process the otoliths and determine: number of increments subsequent to the hatching and saltwater entry check; width of these increments along a standard axis in the posterodorsal quadrat of the otolith; mean increment width and associated error term for each 50 fish group.

3. Zooplankton, Epibenthic Pump, and Meiofauna Samples

Upon transport to the Auke Bay Laboratory, the samples will be logged in by sample number. A total of 96 zooplankton samples, 450 epibenthic pump samples, and 360 meiofauna core samples will require processing.

4. Hydrocarbon samples

A total of 32 mussel samples and 472 sediment samples (counting triplicates) will be collected. All hydrocarbon samples collected in the course of this study will be prioritized by the Hydrocarbon Analysis project as to if and when the samples will be processed. Procedure for analysis of these samples is detailed in the Hydrocarbon Analysis study plan. (Technical Services Study No. 1)

5. Sediment analysis

A total of 54 sediment samples each from component 2 and 54 from component 3 will be collected for organic carbon and nitrogen analysis and to quantify the sediment composition. Processing of these samples will also be let to a qualified contractor.

DATA ANALYSIS

Component 1 (Objective D)

Two approaches will be used to compare abundance and size of juvenile salmon, and stomach fullness and relative biomass of stomach contents: non-parametric comparisons of paired oiled and non-oiled locations, and analysis of variance (ANOVA). The Wilcoxin matched-pairs signed-rank test (Daniel 1978) contrasts the differences between the a priori pairs of oiled and non-oiled locations for cells that match in terms of time and habitat. In the full analysis of variance model, five factors will be considered: oil/no-oil (fixed), time (fixed), bay/corridor (fixed), location (specific sampling location nested within bay/corridor), and habitat type (fixed). To confirm probability levels for the main factor of interest (oil), a randomization procedure will be used to generate distribution-free significance levels.

Nominal growth rates between oiled and non-oiled areas will be compared using a exponential growth model, and comparing the regression slopes of Ln weight over time with analysis of covariance (Zar 1974). ANOVA will be used to compare mean otolith increment widths using a partially hierarchal design (Winer 1971) involving three factors: year, oil/no-oil, and bays nested within oil/no-oil. Condition of juvenile salmon will be compared between oiled and non-oiled areas using least squares regression of the natural logarithms of weight and length (Cone 1989). Percent similarity indexes (Whittaker 1975) will be calculated for feeding habits between oiled and non-oiled areas, between bays and corridor locations, and between 1989 and 1990.

Component 2 (Objective E)

Abundance, percent gravid females, and percent total harpacticoids for primary prey species of juvenile salmon will be compared between heavily oiled and lightly oiled beaches using ANOVA. Because the three embayments will be sampled at different times, differences between bays are not of interest as they could be an artifact of sampling time. Thus each embayment will be considered a separate experiment using a nested ANOVA to compare lightly and heavily oiled transects. The transects will be nested within oil contamination levels. An alternate analytical approach will be to use regression to examine the relationship between abundance of the to amount of oil in the sediment, as well as the substrate composition, macrophyte coverage, and carbon and nitrogen levels in the sediments.

Component 3 (Objective F)

Abundance of total meiofauna and harpacticoid copepods in the experimental sediments will be compared using a three factor, fully-crossed ANOVA (Winer 1971). The factors are location of the sediments, level of oil contamination in the sediments, and time.

Data and Sample Archival

All field and laboratory data forms generated through the course of this study will be placed in notebooks numbered according to the Auke Bay Laboratory Oil Spill Notebook Tracking System (NTS). All field notes will be similarly cataloged. Trip reports for each sampling cruise and study plans will also be archived within the NTS. Copies of computer data files will be maintained on two microcomputer hard drives, as well as rotating floppy disk back-up kept in a locked cabinet.

Table 1. Location of sample sites in Prince William Sound listed as a priori pairs.

Location	Type	Oil
Herring Bay	Bay	Yes
McClure Bay	Bay	No
Snug Harbor	Bay	Yes
Long Bay	Bay	No
Prince of Wales Passage	Corridor	Yes
Culross Passage	Corridor	No
Knight Island Passage	Corridor	Yes
Wells Passage	Corridor	No

BIBLIOGRAPHY

Bailey, J.E., B.L. Wing, and C.R. Mattson. 1975. Zooplankton abundance and feeding habits of fry of pink salmon and chum salmon in Traitor's Cove, Alaska,with speculations on the carrying capacity of the area. Fish. Bull. 73:946-961.

Babcock, M. M. 1985. Morphology of olfactory epithelium of pink salmon, Oncorhynchus gorbuscha, and changes following exposure to benzene: a scanning electron microscope study,p. 259-267, In J. S. Gray and M. E. Christiansen (eds), Marine biology of polar regions and stress on marine organisms. John Wiley & Sons.

Barnard, D. R. 1981. Prey relationships between juvenile pink (Oncorhynchus gorbuscha) and chum (O. Keta) salmon in Prince William Sound, Alaska. M. S. Thesis, University of Alaska, Fairbanks.

Bax, N.J. 1983. Early marine mortality of marked juvenile chum salmon released into Hood Canal, Puget Sound, Washington, in 1980. Can. J. Fish. Aquat. Sci. 40:426-435.

Bodin, P. 1988. Results of ecological monitoring of three beaches polluted by the 'Amoco Cadiz' oil spill: development of meiofauna from 1978 to 1984. Mar. Eco. Prog. Ser. 42: 105-123.

Bonsdorff, E. 1981. The Antonio Gramsci oil spill impact on the littoral and benthic ecosystems. Mar. Pollut. Bull. 12(9):301-305.

Caldwell, R. S., E. M. Caldarone, and M. H. Mallon. 1977. Effects of a seawater-soluble fraction of Cook Inlet crude oil and its major aromatic components on larval stages of the Dungeness crab, Cancer magister Dana. p. 210-220 In D. A. Wolfe (ed), Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms. Pergamon Press, Oxford.

Cooney, R. T., D. Urquhart, R. Neve, J. Hilsinger, R. Clasby, and D. Barnard. 1978. Some aspects of the carrying capacity of Prince William Sound, Alaska, for hatchery released pink and chum salmon fry. Univ. Alaska, Sea Grant Rep. 78-4. 102 p.

Cooney, R.T., D. Urquhart, and D. Barnard. 1981. The behavior, feeding biology and growth of hatchery-released pink and chum salmon fry in Prince William Sound, Alaska. Alaska Sea Grant Report 81-5. 114 pp.

Cordell, J.R. 1986. Structure and dynamics of an epibenthic harpacticoid assemblage and the role of predation by juvenile salmon. M.S. Thesis, Univ. Wash., Seattle. 134 pp.

Cordell, J.R. and C.A. Simenstad. 1989. Epibenthic harpacticoid copepods as indicators of wetland fitness, p. 422-431, In Proceedings First Annual Puget Sound Research Symposium.

Coyle, K. O. and A. J. Paul. 1988. Zooplankton population and biomass in Auke Bay during the spring diatom bloom, 1985-1987. 1987 APPRISE report; University of Alaska SFOS APP87-100.

Coyle, K. O. and A. J. Paul. 1989. Zooplankton population and biomass. 1988 APPRISE report; University of Alaska SFOS APP88-200.

Daniel, W. W. 1978. Applied nonparametric statistics. Houghton Mifflin Co., Boston. 510 pp.

Foerster, R.E. 1968. The sockeye salmon. Fish. Res. Bd. Can. Bull. 162, 422 p.

Fulton, J. D. 1983. Seasonal and annual variations in net zooplankton at Ocean Station P, 1956-1980. Can. Fish. Aqua. Sci. Data Rept. No. 374. 65 pp.

Godin, J.-G.J. 1981. Daily patterns of feeding behavior, daily rations, and diets of juvenile pink salmon (Oncorhynchus gorbuscha) in two marine bays of British Columbia. Can. J. Fish. Aquat. Sci. 38:10-15.

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.

Hargreaves, N. B. and R. J. LeBrasseur. 1985. Species selective predation on juvenile pink (Oncorhynchus gorbuscha) and chum (O. keta) by coho salmon (O. kisutch). Can. J. Fish. Aquat. Sci. 42:659-668.

Hartt, A.C. 1980. Juvenile salmonids in the oceanic ecosystem--the critical first summer. In Salmonid ecosystems of the North Pacific, W.J. McNeil and D.C. Himsworth, eds., p. 25-57. Oreg. State Univ. Press.

Healey, M.C. 1978. The distribution, abundance and feeding habits of juvenile Pacific salmon in Georgia Strait, British Columbia. Fish. Mar. Serv. Tech. Rep. 788, 49 p. Dep. Fish. Environ. Pac. Biol. Stn. Nanaimo, B.C.

Healey, M. C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. In W. J. McNeil and D. C. Himsworth (eds.), Salmonid ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis. 331 pp.

Healey, M. C. 1982. Timing and relative intensity of size-selective mortality of juvenile chum salmon during early sea life. Can. J. Fish. Aquat. Sci. 39:952-957.

Helle, J.H. 1980. Influence of marine environment in age and size at maturity, growth, and abundance of chum salmon from Olsen Creek, Prince William Sound, Alaska. Ph.D. Thesis, Oreg. State Univ.

Kaczynski, V. W., R. J. Feller, and C. Clayton. 1973. Trophic analysis of juvenile pink and chum salmon in Puget Sound. J. Fish. Res. Board Can. 30:1003-1008.

Landingham, J. H., and P. D. Mothershead. 1988. Feeding habits of juvenile pink salmon in nearshore and offshore areas of Auke Bay. p. 450-469 In APPRISE 1988 Annual Report, Vol. 1. School of Fish. and Ocean Science, University of Alaska, Fairbanks.

LeBrasseur, R. J. and R. R. Parker. 1964. Growth rate of central British Columbia pink salmon (Oncorhynchus gorbuscha). J. Fish. Res. Board Can. 21:1101-1128.

Milliken, G. A. and D. E. Johnson. 1984. Analysis of messy data, volume I: designed experiments. Van Nostrand Reinhold, New York.

Mortensen, D. G. and A. C. Wertheimer. 1988. Residency and growth of juvenile pink salmon (Onncorhynchus gorbusha) in Auke Bay, Alaska. 1987 APPRISE report; University of Alaska SFOS AAP87-100.

Murphy, M.L., J.F. Thedinga, and K V. Koski. 1988. Size and diet of juvenile Pacific salmon during seaward migration through a small estuary in southeastern Alaska. Fishery Bulletin, 86:213-222.

Nichelson, T. E. 1986. Influences of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon (Oncorhynchus kisutch) in the Oregon production area. Can. J. Fish. Aquat. Sci. 43:527-535.

Parker, R.R. 1968. Marine mortality schedules of pink salmon of the Bella Coola River, central British Columbia. J. Fish. Res. Bd. Can. 25:757-794.

Parker, R.R. 1971. Size selective predation among juvenile salmonid fishes in a British Columbia inlet. J. Fish. Res. Bd. Can. 28:1503-1510.

Pielou, E.C. 1975. Ecological diversity. John Wiley and Sons. New York. 165 pp.

Pinkas, L., M. S. Oliphant, and I. L. K. Iverson. 1971. Food habits of albacore, bluefin tuna and bonito in California waters. Calif. Dep. of Fish and Game Bull. 152:1-64.

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. NOAA Tech. Mem. NMFS F/NWC-67. 128 p.

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 gorbuscha.p. 503-507, In 1975 Conference on prevention and control of oil pollution. American Petroleum Institute, Washington, D. C.

Ricker, W.E. 1976. Review of the growth rate of and mortality of Pacific salmon in salt water, and non-catch mortality caused by fishing. J. Fish. Res. Bd. Can. 33:1483-1524.

Schwartz, J. P. 1985. Effects of oil-contaminated prey on the feeding and growth rate of pink salmon fry Oncorhynchus gorbuscha. Pp. 459-476 in, Vernberg, F. John, Frederick Thurberg, Anthony Calabrese, and Winona Vernberg (eds.), Pollution and Physiology of Marine Organisms. U. South Carolina Press. Columbia, S.C. 545 pp.

Stacey, B. M. and B. M. Marcotte 1987. Chronic effect of No. 2 fuel oil on population dynamics of Harpacticoid copepods in experimental marine mesocosms. Mar. Ecol. Prog. Ser. 40:61-68.

Taylor, C. C. 1953. Nature of variability in trawl catches. Bull. U. S. Fish. Wildl. Serv. 83:144-166.

Taylor, S.G. 1977. The effect of timing of downstream migration on marine survival of pink salmon. M.S. Thesis. Univ. Alaska, Southeastern Senior College, Juneau, 40 p.

Taylor, S.G. 1988. Inter- and intra-annual survival of pink salmon (Oncorhynchus gorbuscha) returning to Auke Creek, Alaska in 1986 and 1987. p. 545-572, In APPRISE Annual Report, Vol. 1. School of Fish. and Ocean Science, University of Alaska, Fairbanks.

Taylor, S. G., J. H. Landingham, D. G. Mortensen, and A. C. Wertheimer. 1987. Pink salmon early life history in Auke Bay: Residence, growth, diet and survival. p. 273-318, In APPRISE Annual Report-1986. Vol. I: Technical Report.

School of Fisheries, University of Alaska, Juneau.

Urquhart, D.L. 1979. The feeding, movement, and growth of pink salmon fry released from a hatchery in Prince William Sound, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 111 p.

Vogel, A. H. and G. McMurray. 1986. Seasonal population density distribution of copepods, euphausiids, amphipods and other holoplankton on the Kodiak shelf. Outer Continental shelf Environmental Assessment Program. Final reports of Principal Investigators 46:423-659.

Volk, E.C., R.C. Wissmar, C.A. Simenstad, and D.M. Eggers. 1984. Relationship between otolith microstructure and the growth of juvenile chum salmon (Oncorhynchus keta) under different prey rations. Can. J. Fish. Aquat. Sci. 41:126-133.

Walters, C.J., R. Hilborn, R.M. Peterson, and M.M. Staley. 1978. Model for examining early ocean limitation of Pacific salmon production. J. Fish. Res. Bd. Can. 35:1303-1315.

Whittaker, R. H. 1952. A study of summer foliage insect communities in the Great Smoky Mountains, Ecological Monographs 2(1):1-44.

Whittaker, R. H. 1975. Communities and ecosystems. MacMillan Publishing Co., N.Y. 385 pp.

Winer, B. J. 1971. Statistical principles in experimental design. McGraw-Hill, New York. 907 pp.

Zar, J. H. 1974. Biostatistical analysis. Prentice- Hall, Inc., Englewood Cliffs, NJ.

BUDGET

BUDGET: ADF&G

Salaries	$82.0
Travel	3.0
Contracts	48.0
Supplies	5.0
Equipment	12.0
Total	$150.0

BUDGET: NOAA	Total
Labor	$ 100.0
Travel	15.0
Contractual Services	100.0
Supplies and Materials	25.0
Equipment	10.0
Vessel Support:	150.0
Total	$ 400.0

TOTAL BUDGET

Category	Budget
Personnel Services	$182.0
Travel	18.5
Contractual	140.0
Supplies	30.5
Equipment	21.0
Vessel Support	150.0
Total	$550.0

FISH/SHELLFISH STUDY NUMBER 5

Study Title: Injury to Dolly Varden Char and Cutthroat Trout In PWS

Lead Agency: ADF&G

INTRODUCTION

The goal of this study is to compare the survival and growth of populations of Dolly Varden char (char) and cutthroat trout (trout) differentially affected by the oil spill in PWS. This project is currently in the second year of a three-year study design. Trout and char are estuarine anadromous species that inhabit PWS (Morrow 1980). Unlike anadromous Pacific salmon, trout and char utilize nearshore and estuarine areas for feeding. Their marine migrations are not as extensive as those of Pacific salmon (Morrow 1980). Some of the most important stocks of these species inhabit areas that have been severely impacted by direct contact with oil including Green and Montague Islands and Eshamy Bay (Mills 1988). Since these species commonly live to age 8 (Morrow 1980), the potential exists for both short-term and long-term effects from exposure to oil. Study of these species is crucial in that they represent finfish species that inhabit the most oil-affected areas throughout most of their lives.

The experimental design for this program is based upon the model developed by Armstrong (1970, 1974, 1984) and Armstrong and Morrow (1980) to explain the migratory behavior of anadromous char. This model identifies two patterns of life history, fish spawned in lake systems and fish spawned in non-lake systems. For both groups, juvenile char remain in freshwater residence in their natal stream for up to four years. During their last spring of freshwater residence, they smolt to sea. During late summer or early fall, fish that were spawned in lake systems return to their natal stream to overwinter in the freshwater lake. During the spring, they again emigrate into marine waters and annually return to their natal lake system during late summer or early fall to spawn and overwinter. Fish that were spawned in non-lake systems exhibit a more complex migration. Upon smolting, juvenile char search for a lake system to overwinter. These fish then behave in the same manner as do fish that originate in a lake system except that they return to their natal stream to spawn and then return to their selected lake system to overwinter.

The migratory habits of anadromous cutthroat trout are less well understood than those of anadromous char in Alaska although it appears that they exhibit similar migratory habits to char (Jones 1982). Trout, however, spawn in the spring as opposed to fall for char.

It is hypothesized that two detrimental impacts on these species could result from the presence of large amounts of crude oil in marine waters: (1) reduced survival; and (2) reduced growth. To test whether there was a measurable impact, three stocks of trout and char that over winter in watersheds that issue into a marine environment which has been directly exposed to oil (treatment group) and two stocks of trout and char that over winter in watersheds that issue in unoiled areas (control group) were selected for study.

Significant changes in stock abundance, composition, or dynamics from the initial emigration of stocks within the treatment group as compared to stocks from the control group is assumed to be due to contact with the oiled marine waters. Evidence from the literature indicates that marine migrations can range up to 116 kilometers for char (Armstrong 1974) and 80 kilometers for trout (Jones 1982). Armstrong's model of migratory behavior provides the basic framework for this study. First, each of the study streams represents a stock of fish that annually homes to that specific over wintering stream. Second, since over winter residency occurs entirely in freshwater, fish sampled during the 1989 spring emigration had not yet encountered oiled waters. Given this, the first sample from each stream (the emigration during 1989) provides the baseline data for stocks in control and treatment.

OBJECTIVES

A. Test if there is no difference in annual survival rates of char and cutthroat trout between treatment and control groups during 1989-90 (the test will be done given a level of significance of alpha = 0.05.);

B. Test if there is no difference in annual growth rates of char and cutthroat trout between treatment and control groups during 1989-90 (the test will be done given a level of significance of alpha = 0.05.);

METHODS

Trout and char were still in freshwater residence at the time of the spill, and the opportunity existed to sample these fish during their 1989 emigration prior to any potential exposure to an oiled marine environment. Data collected during 1989 became the baseline for each system. Therefore, in addition to comparisons between treatment and control, comparisons are also possible for each stream within treatment and control between subsequent years' data and the 1989 baseline.

Each study stream consists of a freshwater lake-river system that: (1) is a tributary to marine waters that were either impacted by large quantities of oil (treatment) or received virtually no oil (control); and (2) contains stocks of anadromous trout and char.

A weir will be installed and completely block each study stream prior to the initiation of the 1990 spring emigration. A smolt weir for sockeye salmon will operate at the outlet of Eshamy Lake as part of F/S Study #3. Sampling for char and trout will be conducted in conjunction with this project.

Char greater than 250 mm in length will be initially classified as mature (Blackett 1968). At the conclusion of this year's sampling, length frequency data will be analyzed to identify more precise classifications for immature and mature fish.

All emigrating trout and char at each weir site will be counted and measured from tip-of-snout to fork-of-tail to the nearest millimeter. Trout and char greater than 199 mm will be tagged with numbered Floy FD-68 anchor tags and fish under 199 mm and greater than 149 mm will be tagged with numbered Floy Fabric anchor tags. All tagged fish will have their adipose fin removed to estimate tag loss.

If all fish can be censused and examined for tags in all years, survival will be known for each system. Annual survival will be estimated for immature and mature trout and char. The mortality rate of spawning char is known to be high, particularly for males (Armstrong 1974) and it is probable that the same is true for trout. Therefore, the rate of survival estimated for immature char and trout will be used to test the hypothesis of equal survival between treatment and control groups.

The hypothesis of equal survival will be tested using a chi-square statistic. However, if unknown numbers of fish can be expected to be lost past the weir (due to such events as weir washout), it will not be possible to directly estimate survival from the numbers released and returned. Instead survival will be estimated using mark-recapture methods. Estimates of survival (Seber 1982) from a mark-recapture experiment with their 95% confidence intervals at three levels of abundance were examined to estimate the sample goals required to detect significant differences in survival.

The hypothesis of equal growth will be tested by analysis of individual growth rate. Incremental growth for individuals will be computed from recaptured fish. An Analysis of Variance will be conducted with stocks of char or trout serving as replicates within the treatment group. Years, and possibly initial length, will serve as factors in the design. Differences in average growth rates between control and treatment groups will be attributed to some external disturbance so long as initial length of fish is used as a covariate.

During the spring sampling, weirs will be used to count and sample the emigration of trout and char from study streams. Weirs will be installed approximately 0.5 km upstream from the saltwater terminus of the streams. The weirs will be operated by a two-person crew from mid- April to early July. Downstream live traps will be installed.

All fish captured in the trap will be examined for presence or absence of tags, tag scars, and adipose fins. Each fish containing a tag from 1989, a tag scar, or missing its adipose fin will be considered one recapture event. Recaptured fish with missing tags will be retagged. Fish with no visible tag scar and containing their adipose fin (not tagged in 1989) will also be tagged. Each fish captured will be identified, counted, and measured (tip-of-snout to fork-of-tail to the nearest mm). Scale smears will be collected from the preferred area from all cutthroat trout and placed individually on acetate slides in coin envelopes. Date, species, sex (if identifiable from external maturation characteristics), and length will be recorded for each fish. Recapture events will be recorded separately for fish containing tags and fish with missing tags. Tag numbers will be recorded for each recapture and each fish tagged.

All fish found dead impinged on the weir or in the live box will be examined for presence of tags and adipose fins, identified, and measured as outlined above. Sex and maturity will be determined by internal examination, and sagittal otoliths will be collected. Date, species, sex, length, maturity, and tag number will be recorded. Fish containing tags, tag scars or missing adipose fins will be recorded as recaptures.

Estimates of annual survival will be computed for each study site through analysis of tag returns. If all emigrating fish can be examined for marks, the estimates of annual survival (S) can be simply computed as:

$$S = m_2/R_1$$

where:

m_2 = number of fish recovered in year y+1
R_1 = number of fish tagged in year y.

The Jolly-Seber three-sample method (Seber 1982) found in the Appendix will be used in the event that each emigrating fish cannot be examined at the weirs. Buckland's program RECAP (1980) will be used to generate the estimates and variances.

The sampling event for the purposes of the mark-recapture experiment is the emigration of trout and char past the weirs. All emigrating fish must cross the weir and therefore are assumed to be equally vulnerable to being sampled. The assumption of equal survival of tagged fish will be tested for the different tag groups and for the different length classes using chi-square statistics. Tag loss will be estimated for fish tagged in 1989, as all tagged fish will also have their adipose fin-clipped.

If all weirs hold, the hypothesis of equal survival will be tested using a chi-square test for independence. Given a survival rate from immature to mature fish of greater than 15% the test will be able to detect differences of 7% or more (alpha = .05). If the weirs do not hold and all char are not sampled at the weir, during emigration during the second and third year of the experiment; the 95% confidence intervals of the survival estimated from the multi-year mark-recapture experiments will be compared to test for significant differences. In order to examine the effect of initial length on subsequent survival, the tests and estimates will be stratified by tagging length, and if possible a logistic regression will be used to estimate this effect.

Annual individual growth will be calculated from the tag data as the difference between length at time of release and length at time of recovery. An Analysis of Variance will be used to test for significant differences in growth between fish from control and treatment groups. Variation due to differences in years and initial length can be controlled for through the use of a block and covariate in the linear model if necessary. The power to detect a 5% difference in the growth rate of fish from treatment and control areas is estimated to be 90%.

The assumption of normality will be tested using Kolomogorov's D statistic. In all likelihood the data will not be normally distributed and a logarithmic or a rank transformation will be necessary.

The homogeneity of variance assumption will be tested with a Bartlett's test. Again, if the assumption is not valid a transformation will be used.

BIBLIOGRAPHY

Armstrong, R.H. 1970. Age, food, and migration of Dolly Varden smolts in Southeastern Alaska. J. Fish. Res. Bd. Canada 27:991-1004.

_____. 1974. Migration of anadromous Dolly Varden (Salvelinus malma) in southeastern Alaska. J. Fish Res. Board Can. 31:435-444.

_____. 1984. Migration of anadromous Dolly Varden char in southeastern Alaska - a manager's nightmare. p. 559-570. In L. Johnson and B.L. Burns [eds.] Biology of the Arctic char, Proceedings of the International Symposium on Arctic Char, Winnipeg, Manitoba, May, 1981. Univ. Manitoba Press, Winnipeg.

Armstrong, R.H. and J.E. Morrow. 1980. The Dolly Varden char. p. 99-104. In Balon, E.K. [ed.] Chars: salmonid fishes of the genus Salvelinus. Dr. W. Junk b.v., Publisher. The Hague, Netherlands.

Blackett, R. F. 1968. Spawning behavior, fecundity and early life history of anadromous Dolly Varden Salvelinus malma (Walbaum) in southeastern Alaska. ADF&G Research Report. 6:85 p.

Buckland, S.T. 1980. A modified analysis of the Jolly-Seber capture-recapture model. Biometrics 36: 419-435.

Clutter, R. and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. International Pacific Salmon Fisheries Commission, Bulletin 9. 159 pp.

Hepler, K., A. Hoffmann, and P. Hansen. 1989. Injury to Dolly Varden char and cutthroat trout in Prince William Sound. State/Federal Natural Resource Damage Assessment Preliminary Status Report Draft, January 1990. Fish/Shellfish Study Number 5. Alaska Department of Fish and Game, Sport Fish Division, Anchorage.

Jones, D.E. 1982. Development of techniques for enhancement and management of cutthroat trout in southeast Alaska. Alaska Department of Fish and Game. Annual Report of Progress, Project AFS-42, 23(AFS-42-10-B): np.

Mills, M.J. 1988. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 2. 142 pp.

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company, Anchorage, Alaska. 248 pp.

Roth, K.J., C. Whitmore, and P. Hansen. 1990. Prince William Sound and Gulf of Alaska sport fishery harvest and effort, 1989. State/Federal Natural Resource Damage Assessment Preliminary Status Report Draft, January 1990. Fish/Shellfish Study Number 6. Alaska Department of Fish and Game, Sport Fish Division, Anchorage.

Seber, G. A. F. 1982. Estimation of animal abundance and related parameters. 2nd edition, Griffin & Company, London. 655 pp.

BUDGET: ADF&G

Salaries	$ 228.0
Travel	6.0
Contracts	37.3
Supplies	18.7
Equipment	0.0
Total	$ 290.0

FISH/SHELLFISH STUDY NUMBER 7a

Study Title: Injury to Pink/Chum Salmon Spawning Within Lower Cook Inlet and Kenai Fjords

Lead Agency: ADF&G

INTRODUCTION

Wild stocks of pink and chum salmon are a major ecosystem component in the outer Kenai Peninsula and Lower Cook Inlet area, immediately "down current" from PWS. Salmon represent a very important food source for marine mammals (sea lion, seals), terrestrial mammals (bear), and a wide variety of bird species (eagles, etc.). In addition, these wild stocks of pink and chum salmon are harvested commercially. In 1988, the year before the oil spill, the ex-vessel value of the commercial catch of wild and hatchery stocks of salmon from the lower CIK area was more than $8.2 million. Salmon are also very important to the sport, subsistence, and personal use fisheries. The future abundance of wild stocks of pink and chum salmon in the lower CIK areas may be adversely impacted as their intertidal spawning areas were affected by the oil spill. This project was designed to evaluate the distribution of pink and chum salmon spawning in intertidal and upstream areas as a result of oil contamination from the Exxon Valdez oil spill. This project also provides spawner distribution data for F/S Study No. 8a).

OBJECTIVES

A. Count the numbers of spawning salmon by species and by intertidal and upstream areas for nine streams in the Lower Cook Inlet/Kenai Fjords area.

B. Produce maps of spawner distribution for each stream sampled.

METHODS

This project is designed to evaluate changes in numbers and distribution of spawning salmon relative to oil contamination from the Exxon Valdez spill of March 1989. Three two-person crews will perform foot surveys of intertidal and upstream portions of nine major pink and chum salmon spawning streams. Port Dick Creek and Island Creek will be surveyed every other day by the first crew, Humpy Creek will be surveyed daily by a second crew, and the other six streams will be surveyed at least once a week on a rotating basis by the third crew. The third crew will be flown in and out by aircraft. All surveys will be conducted during low tide between July 7 and September 7.

Streams to be surveyed will be selected using the following criteria:

1. The stream must be included in the existing aerial survey program.
2. The stream was examined in past spawning ground survey programs.
3. A significant fraction of spawning occurs in the intertidal area.

The nine streams studied in the Lower Cook Inlet area during 1989 were Windy Creek Left, Port Dick Creek, Windy Creek Right, and Island Creek in the Kenai Fjords area and Humpy Creek, China Poot Creek, Seldovia River, Tutka Lagoon Creek, and Port Graham Creek. All but one historical alevin density index stream, Rocky River, was examined. Rocky River was not included in the 1989 study because the effects of logging on that river would have complicated analysis.

Of the streams studied in 1989, Windy Creek Left and Port Dick Creek have had oil deposited near the stream mouths, Windy Creek Right and Island Creek had oil floating offshore, and the remainder had no visible impact.

Three of the non-oiled streams in Kachemak Bay, China Poot Creek, Tutka Lagoon Creek, and Seldovia River, will not be studied during 1990 because of logistical problems that inhibit sampling efforts at these sites.

Three new non-oiled streams in the Kenai Fjords area, Tonsina Creek (in Resurrection Bay), South Nuka River and James Lagoon Creek, will be added to facilitate comparisons with oiled streams. All three of these streams have an intermittent history of fry digs.

During each stream survey the following data will be recorded:

1. Stream name;
2. Date and time;
3. Counts of live and dead salmon by observer, species and location in the stream [(1) 0.0-0.6 m, (2) 0.6-1.2 m, and (3) 1.2-1.8 m below mean high water, (4) the upstream (above tidal inundation) egg-fry dig area, and (5) the upstream area above the egg-fry dig];
4. Subjective assessment of count quality: (1) the counts are reasonably accurate, (2) the counts are not accurate and a recount may provide a better estimate (e.g. lots of fish in a deep pool, a glare problem, etc.), (3) the counts are not accurate but a recount will not change the results (e.g. bad viewing conditions due to siltation, wind, rain, etc.).
5. Location of tagged fish, tag type, number, and color (Port Dick Creek and Humpy Creek only).
6. Observers name(s).

During foot surveys the numbers of spawning salmon will be estimated by stream zone for each study stream. Stream zones represent levels of tidal influence; (1) 0.0-0.6 m below mean high tide, (2) 0.6-1.2 m below mean high tide, (3) 1.2-1.8 m below mean high water, (4) the upstream (above mean high tide) egg-fry dig area, and (5) the remaining area above the upstream egg-fry dig area.

Stream zones were marked at each stream during the 1989 season. Intertidal zones in the Lower Cook Inlet/Kenai Fiords area were measured from the mean high tide level due to large differences in mean tidal height between the gulf of Alaska (4 m) and Cook Inlet (6 m) sides of the Kenai Peninsula. The stream bed location of the tide levels 0.0, 0.6, 1.2, and 1.8 m below mean high water were marked with a 0.3 m^2 fluorescent orange plywood rectangle. The markers were numbered consecutively 1 through 4 with number 1 furthest downstream at the 1.8 m below mean high water level. A fifth marker will be added during the 1990 field season to identify the upstream end of the egg-fry dig area (NRDA F/S study 8a). A commercial hand held tide computer (Conex Electro-Systems model TF0290W TideFinder) with time and location corrections will be used to determine tide heights.

Maps for each stream will be rechecked for boundaries between stream zones, distances across the streams within zones, and distances between zone boundaries. Areas of spawning concentration and preference by species within each stream zone will be recorded on the revised maps. These maps will be used later by the Pink and Chum Salmon Egg and Pre-emergent Fry Sampling project (NRDA F/S 8a).

Surveys will be at low tide and progress upstream from the 1.8 m below mean high tide marker (marker number 1). The upstream limit of a survey will be determined by the presence of natural barriers to fish passage (e.g. waterfall, log jam, etc.), the end of the stream, or the absence of spawning salmon.

Counts from each crew member will be recorded as an independent observation. Crew members may either walk together or on opposite banks of stream channels depending on terrain and viewing conditions. Both crew members will walk up stream forks together and not split up. Also, the crew will not divide tasks (e.g. one member counts only live salmon while the other counts only carcasses, etc.). Survey partners will be rotated on a weekly basis to prevent counting bias from being perpetuated. Crews will be assigned to a different stream on each succeeding circuit.

Crews will begin each survey with a "practice count" for a short distance. If their counts differ by more than 10%, they will retrace their steps and search for the cause of the difference (fish in a deep pool not clearly visible to both crew members, sun glare, deep shadow, overhanging vegetation, etc.) and recount as many times as necessary until they are satisfied that they can compensate for visibility problems peculiar to their vantage points. Likewise, crew members may warn each other and are encouraged to discuss counting conditions in anticipation of problems before they begin counting (e.g. discuss depth and breadth of school before counting a deep pool of fish, warn each other of difficult viewing conditions, etc.). Thereafter, each member will count and record their data independently.

Both live and carcass counts will be made while walking upstream. Carcasses will be marked at Humpy Creek and Port Dick Creek (e.g. tail removed) to prevent double counting. Hand tally counters (with 4 banks) will be used when counting. Recounts or stops to record counts can be requested at any time and anywhere by either crew member. At a convenient stopping point (e.g. a log jam, either end of a deep pool, the start or end of silty water, etc.), each crew member will record their counts and rate their counts as follows:

1) the counts are reasonably accurate and a recount would give very similar results,
2) the counts are not accurate and a recount may provide a better estimate (e.g. lots of fish in a deep pool, a glare, wind, or rain problem, etc.),
3) the counts are not accurate but a recount will most likely not change the results (e.g. bad viewing conditions due to siltation, wind, rain, etc.).

If both crew members rate their counts 1 or 3, then proceed to the next stream section and count to the next stopping point. If either or both crew members rate their counts 2, then both crew members recount that section and record the results of the second count. If necessary, both crew members could recount and record the results for a third time. After the third trial, proceed and count to the next stopping point.

Pink salmon will be tagged with individually numbered tags to determine stream life and movement for Port Dick Creek and Humpy creek. These streams will be surveyed on an every other day basis with stream location, tag type, color, and number information recorded for every tagged salmon observed. Stream life is expected to vary over time and between sexes. Fifth (50) fish of each sex will be tagged every other day, over an 11 day period. A beach seine will be used to collect fish at the mouth of the streams for tagging. The color-number combinations for Port Dick Creek will be as follows:

Day	Male	Female	Tag
1	orange (# 1-50)	yellow (#51-100)	Peterson disk
3	orange (# 1-50)	yellow (#51-100)	adhesive tape
5	orange (# 1-50)	yellow (#51-100)	rubber band
7	red (#101-150)	green (#151-200)	Peterson disk

9	red (#101-150)	green (#151-200)	adhesive tape
11	red (#101-150)	green (#151-200)	rubber band

The color-number combinations for Humpy Creek will be as follows:

Day	Male	Female	Tag
1	orange (#201-250)	yellow (#251-300)	Peterson disk
3	orange (#201-250)	yellow (#251-300)	adhesive tape
5	orange (#201-250)	yellow (#251-300)	rubber band
7	red (#301-350)	green (#351-400)	Peterson disk
9	red (#301-350)	green (#351-400)	adhesive tape
11	red (#301-350)	green (#351-400)	rubber band

The numbered Peterson disk will be obtained from commercial sources. The second tag type will be self adhesive tape wrapped around the caudal peduncle with the two free ends attached together and protruding up in to the air with a number written on the tape while the third tag type will be a rubber band around the caudal peduncle with 15 cm of numbered survey's tape attached.

A weir will be installed at Humpy Creek to provide known numbers of fish in the stream. Foot survey counts will be made on an every other day basis while aerial survey counts will be made in conjunction with the Commercial Fisheries Division aerial survey program. There will be no attempt to adjust foot or aerial survey counts to match weir counts as the two are expected to differ. Humpy Creek will be mapped and marked for shallow areas with a clear view of the sky, deep pools with a clear view of the sky, and areas with an overhead canopy. Counts in these areas will be recorded separately as aerial and foot survey counts in these areas are also expected to differ.

Data Analysis

Total number of salmon by species present at the time of the foot survey will be estimated using a simple stratified sampling scheme. Each stopping point will be considered the end of a sampling strata. Thus, a stream zone could encompass many sampling strata. The average and variance of the independent counts will be used to estimate the number of fish present within the strata and the variance about the estimate. Averages will be summed across stream zones to provide estimates of numbers of fish within the zone and zones summed to estimate numbers of salmon present during the survey. Variances will be weighted by the number of fish estimated in the strata and summed across stream zones and stream.

Stream life and its variance will be the average and corresponding variance for the number of days a particular tag lot survives in the stream. Changes through time and by sex will be examined.

Total escapement to each stream will be estimated using the area under the curve method (similar to that described by Johnson and Barrett 1988). The point estimates and variances from the foot surveys along with stream life estimates and variances will be used to estimate total escapement and the corresponding variance.

Statistics that will be estimated include:

1. Number of spawning and dead salmon by species, stream zone, stream, and date and the corresponding variances.
2. Stream life and variance.
3. Total escapement and variance.
4. Adjustment factors to relate aerial and foot surveys to weir counts.

A composite sample of mussels (Mytilus sp.) will be collected at the mouth of each stream for hydrocarbon analysis. A field blank (sample container opened at the collection site, closed and stored as if it contained a sample) and two sample replicates will also be collected. Results of the analysis will be used to document the level of oil impact sustained by the stream. Each sample will consist of enough mussels to provide 10 grams of tissue for analysis. The mussels will be collected from the immediate vicinity of all streams. Collectors will use wooden tongue depressors when possible. All mussels will be above water when collected to prevent contamination by surface hydrocarbons. The sample containers will be pre-rinsed (with dicloromethane) glass jars with teflon lined lids as supplied by I-Chem. The samples will be stored in padlocked containers and kept in a freezer in the Homer ADF&G office. Appropriate chain of custody forms will accompany each sample.

Streams will be divided into 2-3 categories based on levels of hydrocarbon contamination (as determined from 1989 visual observations and hydrocarbon level in mussel tissues from the 1989 and 1990 samples). Counts of salmon by species and stream zone for each stream will be assigned to one of the hydrocarbon categories. Counts and spawner distribution will be compared with historical stream survey data and related to the level of hydrocarbon impact.

BIBLIOGRAPHY

Johnson, B.A. and B. Barrett. 1988. Estimation of salmon escapement based on stream survey data. Alaska Department of Fish and Game. Division of Commercial Fisheries. Regional Information Report No. 4K88-35. Kodiak.

BUDGET: ADF&G

Salaries	$ 96.9
Travel	7.5
Contract	9.6
Supplies	3.3
Equipment	0.3
Total	$ 117.6

FISH/SHELLFISH STUDY NUMBER 7b

Study Title: Injury to Pink Salmon Spawning Areas Within the Kodiak and Chignik Areas

Lead Agency: ADF&G

INTRODUCTION

Large escapements into Kodiak and Chignik streams in 1989 occurred as a result of severely limited commercial fishing opportunities caused by the EVOS. Total pink salmon escapements in 1989 were 20.0 (Kodiak) and 1.4 (Chignik) million fish, whereas target escapement goals were 4.0 and 0.7 million pink salmon in the Kodiak and Chignik areas, respectively. The magnitude of escapement experienced during 1989 is unprecedented and has the potential for adversely impacting future returns of pink salmon through density related factors such as fungus and disease outbreaks at the egg and/or fry stage.

Pink salmon are a major component of the Kodiak and Chignik area ecosystem, providing an important food source for both marine mammals, terrestrial mammals, birds, and other fish and shellfish. Additionally they annually re-charge fresh water and near shore marine environments with nutrients as carcasses decompose after spawning. This species is used for subsistence, sport and commercial purposes. Annual ex-vessel value (1978-1988) of the pink salmon harvest is 14.2 and 1.45 million dollars for the Kodiak and Chignik areas, respectively (Malloy 1989; Thompson and Fox 1989).

Pink salmon commercial fisheries are managed, in part, by controlling escapement which is evaluated by aerial and weir counting methods. Aerial surveys for pink salmon escapement indices using fixed wing aircraft and trained observers have been conducted annually for over 30 years in the Kodiak and Chignik management areas. Total pink salmon escapement and spawner density estimates by index stream, geographical region and management area will provide the basis for quantifying the effects of large escapements realized during 1989, on forthcoming brood year returns. Estimates of total available pink salmon spawning habitat will permit assessment of production from empirical escapement densities, and allow for determination of optimum spawning density by geographical area which will be useful for restoration efforts, if needed.

OBJECTIVES

A. Estimate total pink salmon escapements for streams where historic pre-emergent sac fry density data exist. This includes 44 Kodiak and 18 Chignik streams.

B. Define the distribution of spawning pink salmon for index streams within the Kodiak and Chignik management areas. This entails mapping and photographing spawner distribution.

C. Estimate total available spawning habitat for index streams within the Kodiak and Chignik management areas.

METHODS

There are two integral components of this investigation: 1) weir counts and repeated aerial and foot surveys for escapement and stream life calculations, and 2) stream surveys for collection of spawning habitat data necessary for calculating total available spawning habitat.

Trained observers will conduct aerial surveys using fixed wing aircraft on the 44 Kodiak and 18 Chignik pre-emergent index streams. Surveys will be conducted weekly on each index stream with the program continuing until at least seven surveys over the spawning period have been completed or when spawner counts have decreased to less than 10 percent of the observed peak count. Additional non-index streams (342 Kodiak and 72 Chignik) will be surveyed as time and aircraft availability permit. The following information for each survey will be collected: 1) stream name and statistical number; 2) date, weather conditions, fish visibility rating (poor, fair or good) and time; 3) observer, aircraft type and pilot; 4) number of live and dead fish of each species (in bay, mouth and stream); and 5) general survey comments. Data will be recorded on standard forms suitable for data entry into the regional survey database. The observer, upon completion of surveys for a particular index stream, will map spawner distribution and designate the percent of spawning area used. Aerial photographs will be taken of spawner distribution for all index streams surveyed.

Counting weirs will be located at Akalura, Litnik, Saltery, Paramanof, Barling, and Uganik (Pillar Creek will be monitored by foot survey). Pink salmon weir counts will be made daily and recorded on standardized forms. Once every three days throughout the spawning period, foot surveys will be conducted by weir crews and additional personnel to enumerate live and dead fish by species. Data collected during stream surveys will be recorded on standardized forms. Daily weir count and foot survey data will not be reported until after the project has been completed. Aerial surveys will be completed for all weired index streams with a minimum frequency of one survey per week. Data collected during these surveys will be kept separate from the routine aerial survey data. Information collected for this study component will allow for calculation of stream life by system, in-stream population estimates, and aerial survey calibration.

At each weir where stream life is being estimated, adult pink salmon will be tagged with 0.3m, color coded Floy tags with a marking rate of 200 per week. Tagging will commence approximately July 21st and continue for four weeks. Tags will be affixed on a single day each week by capturing fish in a trap located on the upstream side of each weir. Each week will have a specific tag color for identification of that tagging lot. Recovery effort will consist of enumeration of specific color coded fish during foot surveys and tags will be recovered and counted from mortalities.

During the 1989 field season, total available spawning habitat was estimated for 31 Kodiak and 14 Chignik preemergent index streams. The remaining 17 index streams will be surveyed in 1990 to determine total available spawning habitat.

Relying upon previously constructed maps of Kodiak and Chignik index streams with defined limits of historic spawner distribution, total and available stream length will be calculated. The available stream length component will be divided into 300 meter sections, which will be randomly selected for surveying. Within each section, 12 transects spaced 25 meters apart will be run perpendicular to the stream bank.

Pink salmon spawning habitat can be envisioned as a continuum of water velocity, depth, substrate size and embededness. According to Raleigh and Nelson (1985), substrate size and water velocity have the greatest influence on spawning success of pink salmon, however, substrate embededness may also have an impact (Platts et. al. 1983). At each transect surveyed, stream width, water velocity, depth and substrate embededness will be assessed. Values used for these criteria are founded upon averages derived from the literature (Andrew and Geen 1960; Chambers 1956; Divinin 1952; Krueger 1981; Neave 1966; Wilson et. al. 1981). Available spawning habitat will be considered as an area along a transect where depth is a minimum of 15.2 cm, substrate size is within 0.6 to 13.8 cm, water velocity is 0.3 to 0.9 m/sec and substrate embededness is such that gravel is displaced without excessive foot pressure. Spawning habitat will be recorded as a percent of the total area encompassed by a one meter band along the transect line. Data will be entered onto standardized forms and later entered into the regional database. All field personnel responsible for data collection will have prior experience with assessing habitat variables.

An additional task of the spawning habitat inventory program will be to calculate total spawning area for all of the spawning riffles sampled in the pre-emergent fry dig study (F/S Study 8b). Estimates will be derived for 44 Kodiak and 18 Chignik Area streams. The exact location and approximate dimensions for each riffle will be obtained from detailed maps of individual index streams and from consultation with pre-emergent fry dig personnel. Length of the riffle will be measured on a straight line transect measure, while width measures will be made one meter apart on both sides of the line for the entire length of the riffle. All measurements will be in meters and recorded on standardized forms. Only substrate size, velocity and substrate embededness variables from the above methods will be used to delineate spawning habitat in this context.

Stream life of pink salmon is the length of time an adult is alive in the fresh water environment. In 1989, stream life estimates were successfully derived from weir and foot survey counts incorporated into the Johnson and Barrett (1988) model for two Afognak Island systems. Weir and foot survey counts of both live and dead fish collected during 1990 will provide for a maximum of 30 data points per system to be available for stream life analysis. Two analytical approaches will be used to calculate stream life in 1990. The first will be identical to that used in 1989, while the second will use cumulative and periodic dead fish counts. The first approach relies upon the cumulative weir count and periodic foot survey counts being entered into the model and the stream life value being iterated until the model output converges upon the cumulative weir count. The second approach will involve the cumulative dead fish count, periodic foot survey dead counts, and the Johnson and Barrett (1988) model, following the steps outlined above. This analysis, in addition to providing a second stream life estimate, will also allow for calculating a combined washout and predation rate (difference between cumulative dead and cumulative weir counts) which will allow for calibrating counts derived from stream systems surveyed without weirs. Computed stream life values will be statistically tested and if significant differences exist, system specific stream life values will be evaluated based upon the variables stream order, orientation, geomorphology and stream length.

Stream life estimated from tagging data will consist of determining the point at which fifty percent of the tagged fish for a particular color code have been recovered. This approach will be carried out for each of the four weeks for which tags have been affixed. An overall stream life estimate will consist of averaging the estimates for each of the four weeks and also comparisons between systems and weeks following the previously mentioned analytical approach for between system tests.

Instantaneous live pink salmon population size will be estimated from cumulative weir counts and periodic (every three days) foot survey counts of dead pink salmon, Relying upon either a linear or exponential model with in-stream population estimates and aerial survey counts as parameters, precision of aerial survey counts by geographical location and escapement magnitude can be quantified. From this analysis, calibration factors can be determined for use in total escapement estimation procedures.

Temporal aerial survey escapement counts of pink salmon in spawning streams are, depending upon the frequency and timing of the surveys, related to total or cumulative escapement. Defining and quantifying variables or relationships that allow transformation of aerial survey counts into reliable estimates of total escapement is the major task. The Johnson and Barrett (1988) geometric model is one such approach to estimating total escapement. Two data components are required for the algorithm, escapement counts over time and stream life. The unit of measurement is area of the spawner abundance curve derived from a series of survey counts. Two segments comprise the analytical phase of the model, the first is calculating number of fish present between survey counts and the second is deriving total escapement.

Total escapement accuracy, according to Johnson and Barrett (1988), is related to precision of escapement counts and stream life estimates. The influence that both escapement counts and stream life estimates have on the total escapement estimate will be evaluated. Total escapement estimates will be calculated for all index and non-index streams for both the Kodiak and Chignik management areas where aerial and or foot surveys have been completed. Total escapement will also be estimated for index streams based upon the historic aerial survey data base (1968-1988) so that all data which will be utilized in future analyses will have been derived in a similar fashion.

Available spawning habitat will be determined using equations identified in Cochran (1977) and Wolter (1984), (personal communication, Alan Johnson Regional Biometrician, ADF&G, Kodiak). These equations will allow for calculation of the total available spawning habitat and variances associated with the estimates. The estimates can then be used for density estimates for spawning pink salmon for the 1989 brood year in addition to assessing the relationship between density and subsequent returns from previous brood year spawning events.

To derive estimates of potential egg deposition to pre-emergent fry survival, an estimate of total area available for pre-emergent fry sampling is necessary. The area sampled for an individual fry dig when coupled with the total area estimate will allow for expansion of the fry dig data to an estimate of survival. Total area of sampling riffles will be estimated by using the habitat measures for each riffle and summing over all riffles which are sampled for pre-emergent fry. An estimate for each index stream sampled within the Kodiak and Chignik management areas will be derived. These estimates form the foundation of an analysis component conducted as part of F/S Study 8b.

Spawner distribution maps will be prepared, in part, by observers conducting aerial survey escapement counts as was done for the 1989 return. In addition, aerial photographs will also be obtained and cataloged for reference.

BIBLIOGRAPHY

Andrew, F.J. and G.H. Geen 1960. Sockeye and Pink salmon production in relation to proposed dams in the Fraser River system. International Pacific Fisheries Commission Bull. No.11.

Chambers, J.S. 1956. Research relating to study of spawning grounds in natural areas. U.S. Army Corps. Eng. No. Pac. Div. Fish Eng. Res. Prog. 6pp.

Cochran, W.G. 1977. Sampling Techniques. John Wiley, New York.

Divinin, P.A. 1952. The Salmon of South Sakhalin. Investia-Tinro. 37:69-108.

Frisell, C.A. and W.J. Liss 1986. Classification of stream habitat and watershed systems in south central Oregon. Unpub. Progress report. Oak Creek Lab. Corvalis Or.

Hankin, D.G. and G.H. Reeves 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences. 45:1413-1424.

Johnson, B.A. and B.M. Barrett 1988. Estimation of salmon escapement based on stream survey data: A geometric approach Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak. Regional Information Report. No. 4K88-35. 8pp.

Krueger, S.W. 1981. Freshwater habitat relationships, pink salmon (Oncorhynchus gorbuscha). Alaska Department of Fish and Game, Anchorage. 41pp.

Malloy, L.M. 1989. 1988 Kodiak area salmon management report to the Alaska board of fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak. Regional Information Report. No. 4K89-5. 171pp.

Murphy, M.L., J.M. Lorenz, J. Heifetz, J.F. Thedinga, K.V. Koski, and S.W. Johnson 1987. The relationship between stream classification, fish, and habitat in Southeast Alaska. Tech. Bull. 12., Tongass National Forest. R10-MB-10.

Neave, F. 1966. Salmon of the North Pacific Ocean- Part III. A review of the life history of North Pacific pink salmon in British Columbia. International North Pacific salmon fisheries commission Bull. No. 18:71-78.

Platts, W.S., W.F. Megahan and G.W. Minshall 1983. Methods for evaluating stream, riparian and biotic conditions. U.S. Dept.

of Agriculture, General Tech. Rept. Int-138.

Raleigh, R.F. and P.C. Nelson 1985. Habitat suitability index models and instream flow suitability curves: Pink salmon. U.S. Fish and Wildlife Service. Biol. Rept. 82(10.109). 36pp.

Thompson, F.M. and J.R. Fox 1989. Chignik Management area annual finfish management report, 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak. Regional Information Report NO. 4K89-5. 171pp.

Wilson, W.J., E.W. Trihey, J.E. Baldridge, C.D. Evans, J.G. Thiele, and D.E. Trudgen 1981. An assessment of environmental effects of construction and operation of the proposed Terror Lake hydroelectric facility, Kodiak, Alaska. Arctic Environmental Information and Data center, Univ. of Alaska. Anchorage. 419pp.

Wolter, K. M. 1894. An investigation of some estimators of variance for systematic sampling. Journal of the American Statistical Association. 79:781-790.

BUDGET: ADF&G

Salaries	$251.7
Travel	5.0
Contracts	132.2
Supplies	49.3
Equipment	22.1
Total	$460.3

FISH/SHELLFISH STUDY NUMBER 8a

Study Title: Injury to Pink and Chum Salmon Eggs and Pre-Emergent Fry Within Lower Cook Inlet and Kenai Fjord

Lead Agency: ADF&G

INTRODUCTION

Wild stocks of pink and chum salmon are a major ecosystem component in the outer Kenai Peninsula and Lower Cook Inlet area, immediately "down current" from Prince William Sound. Salmon represent a very important food source for marine mammals (sea lion, seals), terrestrial mammals (bear), and a wide variety of bird species (eagles, etc.). In addition salmon are harvested commercially. In 1988, the year before the oil spill, the ex-vessel value of the commercial catch of wild and hatchery stocks of salmon from the lower Cook Inlet/Kenai Peninsula (CIK) area was more than $8.2 million. Salmon are also very important to the sport, subsistence, and personal use fisheries. The future abundance of wild stocks of pink and chum salmon in the lower CIK areas may be adversely impacted as their intertidal spawning areas were affected by the oil spill. This project continues the evaluation of pink and chum salmon egg to fry survival in the intertidal spawning areas affected by the EVOS.

OBJECTIVES

A. Estimate abundance of pink and chum salmon eggs and pre-emergent fry by intertidal and upstream areas for nine streams in the lower CIK. Six of the streams were studied in 1989. Three unoiled streams in Kachemak Bay were dropped while three Gulf of Alaska streams were added to provide a better comparison of oiled and unoiled streams in the Gulf of Alaska area.

B. Estimate overwinter mortality (egg to pre-emergent fry) of pink and chum salmon eggs.

C. Estimate reductions, if any, in pink and chum salmon pre-emergent fry abundance due to oiling.

METHODS

Sampling will be conducted in two phases: egg-digs performed in October and pre-emergent fry digs conducted in March. The number of streams to be studied is limited by the number of days in October and November with low tides (maximum of +4.0 feet) during daylight hours.

Streams were selected using the following criteria:

1. Sufficiently large adult salmon returns to indicate a high probability of success in egg/fry digging.
2. Past history of egg/fry digging.
3. Streams covered by F/S Study 7a and aerial escapement survey project.
4. Streams can be safely studied during the winter and early spring months.

The nine streams studied during 1989 were Windy Creek Left, Port Dick Creek, Windy Creek Right, and Island Creek in the Kenai Fjords area and Humpy Creek, China Poot Creek, Seldovia River, Tutka Lagoon Creek, and Port Graham Creek in the Cook Inlet area. All but one historical alevin density index stream, Rocky River, was on that list. Rocky was not included in the 1989 study because the effects of logging would have confused the results.

Of the streams studied in 1989, the first two have had oil deposited near the stream mouths, the next two have had oil floating offshore, and the remainder had no visible impact.

Three of the non-oiled streams in Kachemak Bay, China Poot Creek, Tutka Lagoon Creek, and Seldovia River, will not be studied during 1990 because of logistical problems that inhibit sampling efforts at these sites.

Three new non-oiled streams in the Kenai Fjords area, Tonsina Creek (in Resurrection Bay), South Nuka River and James Lagoon Creek, will be added to facilitate comparisons with oiled streams on the Gulf of Alaska. All three were once considered non-index alevin density streams with an intermittent history of fry digs.

Sampling methods are identical for the pre-emergent fry and egg digs. On each sample stream, four zones, 3 intertidal and one above tidal inundation, will be identified and marked by crews conducting stream surveys during F/S Study 7a. The zones are 0.0-0.6 m, 0.6-1.2 m, and 1.2-1.8 m below mean high water, and upstream of tidal inundation.

Separate linear transects will be established in each zone (one transect for each type dig). The transects will run the entire length of the zone. Overlapping of transects will be kept to a minimum to control the influence of fall egg digs on abundance of fry during spring sampling. Fourteen circular digs (56 per stream), each 0.3 m^2 in size, will be systematically dug along each transect using a high pressure hose to flush eggs and fry from the gravel. Eggs and fry will be caught in a specially designed net. Areas where salmon were not observed spawning during the spawning ground surveys (F/S Study 7a) will be avoided. Numbers of live and dead fry by species as well as numbers of live and dead eggs by species will be collected from each 0.3 m^2 dig. Additional information such as date, time, and zone will also be collected.

Eggs and fry will be collected for MFO analysis. A sample of 40 fish will be preserved in a buffered formalin solution.

A composite fry sample will be collected from the intertidal area for hydrocarbon analysis. A field blank (sample container opened at the collection site, closed and stored as if it contained a sample) will also be collected. Each sample will consist of enough fry to provide 10 grams of tissue (about 110 fry) for analysis. The sample containers will be pre-rinsed glass jars with teflon lined lids. The samples will be kept frozen until shipment for processing in Auke Bay. Appropriate chain of custody forms will accompany each sample.

A mixed effects analysis of covariance will be used to test for differences in egg to fry survival due to oiling. The level of hydrocarbon impact will be determined from hydrocarbon analysis of mussels collected in 1989 and 1990 by F/S Study 7a.

Analysis of variance will be used if no suitable hydrocarbon data are available. Degree of oiling as visually assessed by F/S Study 7a will be used to post-stratify streams. Degree of oiling and height in the tidal zone will be treated as fixed effects. Height in the tidal zone is nested within stream, a random effect.

The number of streams sampled is limited by the window of time available for sampling. Power was estimated for the ANOVA using data from the 1975 and 1976 egg and pre-emergent fry digs in PWS. This analysis indicated the ANOVA could detect an increase of 20% (e.g. 10% mortality to 30% mortality) in egg to fry mortality at $\alpha = 0.05$, 90% of the time.

An assessment of lost fry production will be made if differences in egg to fry survival due to oiling are detected. Average survival from unoiled areas will be used to estimate potential fry density in oiled areas. Observed and potential fry densities will then be expanded to estimate total observed and potential fry. The difference between the two estimates will be considered lost fry production.

Specific statistics to be estimated are:

1. Number of dead and viable eggs per square meter by salmon species, stream, and stream zone.
2. Number of dead and live fry per square meter by salmon species, stream, and stream zone.
3. Egg to fry survival by salmon species, stream, and stream zone.
4. Lost production by salmon species, stream, and stream zone.

BUDGET: ADF&G

Salaries	$46.9
Travel	1.7
Contracts	19.7
Supplies	1.3
Equipment	1.4
Total	$71.0

FISH/SHELLFISH STUDY NUMBER 8b

Study Title: Injury to Pink Salmon Egg and Pre-Emergent Fry In the Kodiak And Chignik Management Areas

Lead Agency: ADF&G

INTRODUCTION

Large escapements of pink salmon into Kodiak and Chignik streams in 1989 occurred as a result of severely limited commercial fishing opportunities caused by the EVOS. Total pink salmon escapements in 1989 were 20.0 (Kodiak) and 1.4 (Chignik) million fish, whereas target escapement goals are 4.0 and 0.7 million pink salmon in the Kodiak and Chignik areas, respectively. The escapement magnitude experienced during 1989 is unprecedented and has the potential for adversely impacting future returns of pink salmon through density related factors such as fungus and disease outbreaks at the egg and/or fry stage.

Pink salmon are a major component of the Kodiak and Chignik area ecosystems, providing an important food source for both marine mammals, terrestrial mammals, birds, and other fish and shellfish. Additionally they annually re-charge fresh water and near shore marine environments with nutrients as carcasses decompose after spawning. This species is used for subsistence, sport and commercial purposes. Annually, pink salmon comprise 78% and 31% (1978-1988) of the Kodiak and Chignik salmon harvest, respectively. Ex-vessel value (1978-1988) of the pink salmon harvest is 14.2 and 1.5 million dollars for the Kodiak and Chignik areas (Malloy 1989; Thompson and Fox 1989).

A total of 386 Kodiak and 90 Chignik streams support populations of pink salmon. Pre-emergent sac fry sampling has been conducted in 44 Kodiak and 18 Chignik streams periodically over the last 20 years. These streams, referred to as index streams, provide data which are utilized for projections of returns and potential harvest.

Potential damage caused by the 1989 brood year escapements upon future brood year returns can be quantified by: 1) examination of observed versus expected numbers of live fry/dig produced from potential egg deposition; 2) comparison of 1989 potential egg deposition to pre-emergent fry survival for the odd years 1969 to present; 3) evaluation of numbers of live fry/dig for streams with optimum spawning density versus streams with spawner densities above optimum.

OBJECTIVES

A. Estimate potential egg deposition for all Kodiak and

Chignik pre-emergent index streams.

B. Estimate pink salmon fry density for Kodiak and Chignik index streams.

C. Estimate pink salmon survival from potential egg deposition to pre-emergent fry.

D. Assess changes, if any, of pink salmon pre-emergent fry abundance in 1991 due to the oil spill.

E. Estimate the 1991 adult pink salmon return by using the 1990 fry index data.

METHODS

Potential egg deposition (PED) for each of the 62 Kodiak and Chignik Management Area index streams will be determined using index stream total escapements and fecundity data collected during the 1989 field season. The PED estimates will be based upon average fecundity derived from the relationship of fish length to number of eggs carried and the total escapement estimates derived using the Johnson and Barrett (1988) model.

Pre-emergent sac fry sampling will be conducted on 44 Kodiak and 18 Chignik index streams. A majority of these streams have been frequently and consistently sampled each year. Sampling station (spawning riffles) selection is founded upon pink salmon spawner distribution and specific habitat utilization as recorded from aerial surveys. The number of sampling sites per stream is based upon escapement magnitude, stream size and observed productivity of individual index streams. Generally, smaller streams where escapements average less than 20,000 will have 4-6 sampling stations, 6-9 stations for the larger intermediate sized streams and the most productive streams will have 10-15 stations. Historically, 10 digs have been completed for each station using a pump and associated equipment which hydraulically remove pink salmon eggs and fry (both live and dead) from the stream bed. A collection frame is used to capture eggs and fry as they are displaced from the gravel. Depth of stream bed sampling is 15.0 to 46.0 cm with a duration of 1-3 minutes depending on substrate. After eggs and fry (both live and dead) are enumerated the collection frame is moved to the next dig location and the steps repeated. Sampling is done in an X configuration with equal numbers of digs done above and below the center of the X. Digs which are at the extremes of the configuration are those which are closest to the stream banks. Ancillary information recorded along with egg and fry counts are stream temperature, predator presence, stage of fry development, quantities of egg fragments and evidence of stream bed scouring or shifts (Brennan 1990). Only minor modifications have occasionally beset the above sampling program and were associated with water conditions, ice coverage or flood events which had altered the stream channel. Presently the only modification which will be imposed on the sampling program for 1990 will be that a minimum of 30 digs with at least one live fry be obtained for each stream sampled, regardless of the historic number of digs done for that system (Johnson 1990). Alternative stations for additional digs to meet this constraint will be from established sampling sites. Pre-emergent sac fry sampling will be conducted in a time frame which will minimize the chances of fry emigration prior to sampling.

Determination of egg to pre-emergent fry survival (1989-1990) will be founded upon PED, live fry/dig, and habitat data collected from F/S Study 7b. An estimate of spawning density for all spawning riffles sampled for pre-emergent fry will be obtained from the detailed spawner distribution maps.

Utilizing PED and number of live fry/dig data spanning the odd years 1969 to 1989, analyses will consist of fitting and assessing an empirical relationship. If required for quantifying possible outlying data points, climatological variables (precipitation and mean monthly temperature) will be assessed as possible causative factors. Damage from this analytical standpoint would be live fry/dig values which fall below (descending limb of curve) the range of expected PED. Hypothesis testing using non-parametric tests will be used to assess whether observed differences in number of live fry/dig are statistically significant. A significance level of 0.1 will be used for all statistical analyses.

The observed difference between potential eggs deposited and resultant pre-emergent fry will be designated as fry survival for a given year. The equation which will provide the estimate will be from Snedecor and Cochran (1967, p.520) with N defined as spawning area.

PED in this framework will be determined from the proportion of the total escapement which during odd years utilize this fraction of the overall spawning habitat. Again, data for the odd years 1969-1989 will be used and comparisons of eggs and fry densities for contrasting levels of escapements and years will be made. If needed, climatological conditions will be assessed in relation to calculated survival values. Damage, if any, due to escapement levels experienced in 1989 will be quantified from this method.

This analysis component will take into account available spawning habitat, total estimated escapement and pre-emergent fry dig data. Control streams will be designated based upon a cumulative ranking of escapement and total available habitat in which the overall density of all streams will be 1.3 fish per M^2 or less. All index streams that fall outside of this classification will be designated as treatment streams (those with spawner densities above the calculated optimum of 1.3 fish/M^2). There are 17 control and 14 treatment streams within the Kodiak area and 11 control and 3 treatment streams in the Chignik area. Analysis will consist of comparing the live fry/dig data in composite for the control versus treatment streams. An alternative method will use an independent, mutually exclusive classification method for each index stream. The above (control versus treatment) method incorporates streams with density values that are above the defined optimum for the control group. Index streams (13 Kodiak and 4 Chignik) without available spawning habitat estimates will be included in this analysis when estimates become available.

BIBLIOGRAPHY

Brennan, K.R. 1990. History of the pink salmon Pre-emergent fry sampling program in the Kodiak and Chignik management areas. Alaska Department of Fish and Game. Unpublished manuscript. 12pp.

Johnson, B.A. 1990. Detecting changes in pink salmon (Onchorhynchus gorbuscha) fry density for Humpy Creek, Alaska, and determination of sample size requirements. Alaska Department of Fish and Game, Kodiak. Regional Information Report No. 4k90-3. 6pp.

Johnson, B.A. and B.M. Barrett 1988. Estimation of salmon escapement based on stream survey data: A geometric approach. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak Regional Information Report No. 4K88-35. 8pp.

Malloy, L.M. 1989. 1988 Kodiak area salmon management report to the Alaska board of fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak. Regional Information Report No. 4k89-6. 72pp.

Snedecor, G.W., and W.G. Cochran 1967. Statistical Methods. Iowa State University Press, Ames, Iowa.

Thompson, F.M. and J.R. Fox 1989. Chignik Management Area Annual Finfish Management Report, 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak. Regional Information Report No. 4k89-5. 171pp.

BUDGET: ADF&G

Salaries	$ 86.4
Travel	1.1
Contracts	53.0
Supplies	8.8
Equipment	0.0
Total	$ 149.3

FISH/SHELLFISH STUDY NUMBER 11

Study Title: Injury to PWS Herring

Lead Agency: ADF&G

INTRODUCTION

The oil spill in PWS coincided with the annual migration of Pacific herring Clupea harengus to near-shore spawning areas. In 1989, a significant portion of the spawning area in PWS was located within areas contaminated by oil. Additionally, adult spawning herring and newly hatched juveniles traversed areas impacted by oil and beach cleaning activities.

It was hypothesized that the oil spill would adversely impact adult fish through direct mortality, food shortages, slowed growth, and a possible reduction in fecundity. In addition, herring eggs have been shown to be particularly susceptible to hydrocarbon contamination due to the affinity of hydrocarbon compounds for yolk sac material. Although no significant acute mortality was observed for adult fish in 1989, significant impacts were measured on egg mortality, egg hatching success, and percent viable hatch. Any of these adverse effects have the capacity to reduce the abundance and availability of herring. Adult and juvenile herring, as well as herring eggs, often form an important item in the diet of marine fishes (e.g. salmon and halibut), mammals (e.g. sea lions, seals, and whales), and birds (e.g. cormorants, ducks, puffins, gulls). Herring also support an important commercial fishery within PWS, worth over 12 million dollars in 1988.

The goal of this project is to determine whether the EVOS will have a measurable impact on populations of Pacific herring in PWS. Accurate and precise estimates of population abundance, age structure, weight, and length composition data are needed to accomplish this goal. In addition, the direct effects of oil contamination on spawning success and egg survival will be determined.

OBJECTIVES

A. Expand the normal sampling of herring populations in PWS to increase the precision of herring abundance, age composition, weight, sex ratio, and fecundity estimates. Specifically we intend to:

   Continue to estimate the biomass of the spawning stock of herring in PWS such that the estimate is within ± 25% of the true value 95% of the time;

Estimate the age, weight, length (AWL), and sex composition of herring in PWS during 1989 such that age composition estimates are within ± 10% of their true values 95% of the time;

B. Continue to document the occurrence of herring spawn in oiled and unoiled areas, validating the sites with quantified oil level information obtained from shoreline survey maps and hydrocarbon analysis of 1989 and 1990 herring eggs and mussel tissue.

C. Continue to estimate hydrocarbon contamination of, and physiological impacts on, adult herring by analyzing tissue samples:

Test the hypothesis that the level of hydrocarbons in herring tissues is not related to the level of oil contamination of the area from which the herring were sampled. The experiment is designed to detect a difference of 1.6 standard deviations in hydrocarbon content with the probability of making a type I and type II error of 0.05 and 0.1, respectively.

Estimate the presence and type of damage to tissues and vital organs of herring sampled from oil-impacted and un-impacted areas.

Test the hypothesis that the level of hydrocarbons in herring eggs is not related to the level of oil contamination of the area from which the herring were sampled. The experiment is designed to detect a difference of 1.6 standard deviations in hydrocarbon content with the probability of making a type I and type II error of 0.05 and 0.1, respectively.

D. Continue to estimate the proportion of dead herring eggs from a subsample of study sites in oiled and un-oiled areas that were utilized in the 1989 egg mortality study, expanding the data base and providing sample sites for sample collection of live and preserved eggs. In addition, add an egg loss study at the egg mortality sites to increase the accuracy of the spawn deposition biomass estimates.

E. Continue to estimate the hatching success, viable hatch, occurrence of abnormal larvae, and collect embryonic and larval tissue for sublethal testing including MFO, cytogenetics, RNA/DNA ration analysis, and others by collecting herring eggs from egg mortality sites and control sites in Southeast Alaska (Sitka Sound) and rearing them under laboratory observation.

METHODS

This project will be conducted in three parts: (1) herring spawn deposition estimation; (2) herring age, weight, length, growth, and fecundity estimation; and (3) herring egg survival and egg loss estimation.

Herring Spawn Deposition Estimation

The management of the PWS herring stock is based on a harvest policy established by the Alaska Board of Fisheries which specifies a maximum 20% exploitation rate for the combined harvest of all herring fisheries. The allowable harvest is based on biomass estimates established the previous year modified by the expected growth and survival over the year. While aerial surveys were used to estimate biomass from 1973-87, spawn deposition surveys were performed in 1983 (Jackson and Randall 1983) and 1984 (Jackson and Randall 1984), and began to be used as the primary biomass estimate in 1988 (Biggs and Funk 1988). Aerial surveys are easier to perform than spawn deposition surveys, but aerial survey biomass estimates are not as reliable because of the varying visibility of herring schools from the air and because the residence time of herring schools on the spawning grounds is unknown. Estimates of precision are not available for aerial survey biomass estimates. The ADF&G continues to conduct an annual aerial survey of spawning biomass to provide in season indicators of run timing and location and to collect information on the timing and distribution of spawning activity that is used for planning the spawn deposition survey.

This project represents an augmented program to assess the PWS herring stock's response to the EVOS. The original goal of the 1989 herring spawn deposition survey was to estimate the spawning biomass with a precision such that the biomass estimate would be within ± 25% of the true biomass estimate 95% of the time under optimal survey conditions. Fishery managers determined that this level of precision was acceptable for estimating exploitation rates and forecasting future abundance. If weather or other logistic problems hampered the spawn deposition survey sampling effort, fishery managers were willing to tolerate reduced precision. The EVOS introduced a potentially new and unknown level of mortality on herring stocks. The accuracy and precision of estimates of stock abundance need to be assured from both oiled and unoiled areas (as reflected in objectives 1 and 2). The opportunity to estimate herring biomass with spawn deposition surveys is only available during a relatively narrow two week window. After the oil spill, the number of divers involved in the survey was increased to assure that even if weather problems restricted the available sampling time, sufficient numbers of transects could still be performed. The number of transects was also increased to provide a level of precision such that the biomass estimate would be within ± 25% of the true biomass 95% of the time. The amount of time devoted to skiff surveys of spawning areas was also increased. Skiff survey delineation of spawning area boundaries should help to increase the level of precision of spawn deposition surveys and provides important documentation of the occurrence of herring spawn in oiled and unoiled areas.

The aerial survey project will provide a map indicating the general location of herring spawning areas. A skiff survey will then delineate the boundaries of each spawning area in more detail. Transects will be placed perpendicular to the shoreline at locations selected randomly from the shoreline maps of spawning areas. Divers will swim along the transects and systematically place 0.1 m^2 quadrants at 5 m intervals. Divers will estimate the total number of eggs in each quadrant. All egg-containing vegetation will be removed from a subset of the quadrants for later enumeration of the number of eggs in a laboratory procedure. These enumerated egg counts will be used to correct bias in diver-estimated egg counts and estimate the precision of the diver estimates. The survey design is described in detail by Biggs and Funk (1988), and follows closely the two-stage sampling design of similar surveys in British Columbia (Schwiegert et al. 1985), and in Southeast Alaska (Blankenbeckler and Larson 1982, 1987). The surveys use random sampling at the first stage (transects), and systematic sampling at the second stage (quadrants within transects). Random sampling in the second stage is not feasible because of underwater logistical constraints (Schwiegert et al. 1985). In addition to the two-stage design, the survey is stratified by five areas within PWS (Southeast, Northeast, North Shore, Naked Island and Montague), because of the geographic separation of these areas and the potential for herring in these areas to be discrete stocks.

Mean egg densities along each transect will be combined to estimate an overall average egg density. The observed widths of the spawning bed along each of the transects will be used to estimate the average spawning bed width. The average width, average density, and total spawning bed shoreline length (verified from the skiff survey) will be used to estimate the total number of eggs deposited in each of five area strata established within PWS. Using the average fecundity and sex ratio derived from the AWL sampling portion of this project, the total number of eggs deposited will be converted into population numbers and biomass. Based on the variances obtained during the 1989 survey, 160 transects would be needed to insure that the estimated biomass would have a 95% chance of being within 25% of the true biomass (161 transects were conducted in 1989 with a 95% chance of being within 19% of the true biomass).

Sampling Procedure:

The general locations of spawning activity will be derived from visible milt observed in the water column during scheduled aerial surveys. This information will be compiled and summarized on maps showing spawning locations and the number of days on which milt was observed.

Using this information, skiff surveys will be conducted in season, by members of the spawn deposition dive team, to verify the accuracy of spawning area maps derived from aerial survey data. Diving where herring have spawned is not recommended for at least 5 days after spawning activity has ceased because of water visibility problems caused by milt and because large numbers of sea lions are usually present.

The shoreline area containing herring spawn on the map verified by skiff survey will be divided into the smallest segments resolvable on the scale of the map (0.1 mile or less). A total of 160 of the shoreline segments will be selected at random from all of the spawn-containing shoreline segments. Each transect will be assigned a number and its location drawn on waterproof field maps that can be taken out in the dive skiff. The dive team leader will determine the exact transect location within the randomly selected shoreline segment by identifying a shoreline feature (tree, rock, cliff, etc.) located above the high tide line as the dive skiff approaches the shore, but before bottom profiles, bottom vegetation, or herring spawn are visible from the skiff.

A 0.1 m^2 quadrant constructed of PVC pipe will be used for the sampling frame. A depth gauge and compass will be fastened to the quadrant. Data will be recorded on pre-printed single matte mylar forms attached to PVC clipboards, using a large weighted carpenter's pencil attached to the clipboard. Normally the dive team leader will make egg density estimates and record data while the assistant diver sets and follows the compass course, measures distances, and carries and places the quadrant.

Sampling along the transects will occur in the following manner:

1. A compass course perpendicular to the shoreline at the transect location will be set on the compass attached to the sampling quadrant.

2. The first quadrant will be placed within the first 5 meters of spawn by tossing the quadrant.

3. The lead diver will estimate and record the number of eggs in the quadrant. The number of eggs is normally recorded in units of thousands. The vegetation type, percent cover, substrate, and depth are also recorded.

4. The assistant diver will measure four complete 1 m hand-spans offshore, along the compass course. Halfway through the fifth hand-span, the assistant diver will gently toss the quadrant ahead approximately one-half meter and allow it to come to rest. The lead diver then makes another estimate at the new quadrant location.

5. This process continues every 5 meters until the apparent

end of the spawn is found. Divers will verify the end of the spawn by swimming at least an additional 20 m past the end of the spawn, unless a steep drop-off is encountered.

Data codes have been developed for the vegetation types and species that are encountered in PWS. If more than one is present in the quadrant sampled, the three most common are recorded on the data forms. Percent cover is a simple estimate of the percentage of plant cover that exists within the quadrant sampled (e.g., if half the area is covered, the cover is 50%).

Approximately every fifth quadrant will be used as a special diver calibration sample. Both divers will estimate the number of eggs in the quadrant in a manner such that neither can see the other's estimate. Divers will attempt to remove all egg-containing vegetation and scrape eggs off rock substrate, placing the material in numbered mesh bags. A sample size goal of 80 calibration samples per diver was established, including 20 in each of four vegetation categories (eelgrass, fucus, large brown kelp, hair kelp), based on 1988 and 1989 survey results. Calibration samples should also be spread over a wide range of egg densities. The spawn deposition project leader will track the number of samples collected by each diver by vegetation group and density to ensure that sufficient calibration samples are taken in each category. Upon completing a dive shift, calibration sample material will be removed from the numbered mesh bags and placed in nalgene ziploc bags. Gilson's solution will be poured over the sample so that all material is completely immersed. A label will be made for each sample (preferably in pencil on mylar) containing the transect number, both diver's estimates, date, and vegetation type. Five or 6 calibration sample bags can be stored in a 5 gallon plastic bucket. Samples should not be stacked over one another to prevent spilling and mixing. Procedures for the enumeration of the number of eggs in each calibration sample are described, including the formulas used to prepare Gilson's solution and the other chemicals used for sample processing.

Data Analysis:

Biomass Estimation

The 1990 spawn deposition survey was patterned after the 1988 and 1989 spawn deposition survey in Prince William Sound (Biggs and Funk 1988, Biggs In Press). The overall biomass estimator is:

$$B = \frac{(T \cdot B')}{(1 - R)}; \qquad (1)$$

where:

B = estimated spawning biomass in tonnes,
T = estimated total number of eggs (billions) deposited in an area,
B' = estimated tonnes of spawning biomass required to produce one billion eggs, and
R = estimated proportion of eggs disappearing from the study area from the time of spawning to the time of the survey (egg loss).

The estimates for T and B' are derived from separate sampling programs and are thus independent. Ignoring the unknown variability in R, the estimated variance for the product of the independent random variables T and B', conditioned on R is:

$$\mathrm{Var}(B|R) = \frac{[T^2\mathrm{Var}(B') + B'^2\mathrm{Var}(T) - \mathrm{Var}(T)\cdot\mathrm{Var}(B')]}{(1-R)^2}; \text{ where} \quad (2)$$

Var(B') = an unbiased estimate of the variance of B'; and
Var(T) = an unbiased estimate of the variance of T (Goodman 1960).

Total Number of Eggs (T)

The total number of eggs deposited in an area is estimated from a two-stage sampling program with random sampling at the primary stage, followed by systematic sampling at the secondary stage, using a sampling design similar to that described by Schwiegert et al. (1985). In computing variances based on the systematic second stage samples it is assumed that eggs are randomly distributed in spawning beds with respect to the 0.1 m^2 sampling unit. While this assumption was not examined, in practice the variance component contributed by the second sampling stage was much smaller than that contributed by the first stage, so that violations of this assumption would have little effect on the overall variance. The total number of eggs (T), in billions, in an area is estimated as:

$$T = N \cdot \hat{y} \cdot 10^{-6}, \text{ where} \quad (3)$$

N = $L/\sqrt{0.1}$ = the total number of possible transects;
L = the shoreline length of the spawn-containing stratum in meters;
$\sqrt{0.1}$ = 0.3162 m = width of transect strip;
$\hat{y}$ = average estimated total number of eggs (thousands) per transect; and
10^{-6} = conversion from thousands to billions of eggs.

The average total number of eggs per transect strip (in thousands) is estimated as the mean of the total eggs (in thousands) for each transect strip using:

$$\hat{y} = \frac{\sum_{i=1}^{n} \hat{y}_i}{n}, \text{ where} \qquad (4)$$

$\hat{y}_i$ = $M_i \cdot \bar{y}_i$; and

$\bar{y}_i$ = average quadrant egg count in transect i (in thousands of eggs);

i = transect number;

M_i = $w_i/\sqrt{0.1}$ = number of possible quadrants in transect i;

w_i = transect length in meters; and

n = number of transects actually sampled.

The average quadrant egg count within a transect, $\bar{y}_i$, is computed as:

$$\bar{y}_i = \frac{\sum_{j=1}^{m_i} y_{ij}}{m_i}, \text{ where} \qquad (5)$$

j = quadrant number within transect i,
m_i = number of quadrants actually sampled in transect i, and
y_{ij} = adjusted diver-estimated egg count (in thousands of eggs) from the diver calibration model for quadrant j in transect i.

The variance of T is similar to that given by Cochran (1963) for three stage sampling with primary units of equal size, although in this case the expression is modified because the primary units (transects) do not contain equal numbers of secondary units (quadrants), and the variance term for the third stage comes from the general linear model used in the diver calibration samples:

$$\mathrm{Var}(T) = N^2(10^{-6})^2\left[\frac{(1-f_1)}{n} \cdot s_1^2 + \frac{f_1(1-f_2)}{\sum_{i=1}^{n} m_i} \cdot s_2^2 + \frac{f_1 f_2}{\sum_{i=1}^{n} m_i} \cdot s_3^2\right], \qquad (6)$$

$$s_1^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i - \hat{y})^2}{n-1} = \text{variance among transects},$$

$$s_2^2 = \sum_{i=1}^{n} M_i^2 \sum_{j=1}^{m_i} \frac{(y_{ij} - \bar{y}_i)^2}{n(m_i-1)} = \text{variance among quadrants,}$$

$$s_3^2 = \sum_{i=1}^{n} \sum_{j=1}^{m_i} \mathrm{Var}(y_{ij})$$ = sum of the variances of the individual predicted quadrant egg counts from the diver calibration model,

$$f_1 = \frac{n}{N}$$ = proportion of possible transects sampled, and

$$f_2 = \frac{m_i}{M_i}$$ = proportion of quadrants sampled within transects (same for all transects).

Diver Calibration

Diver observations of vegetation species will be aggregated into four vegetation categories based on structural and phylogenetic similarities of plants in the quadrant: eelgrass, fucus, hair kelp, and large brown kelp. Diver estimates of egg numbers are approximately proportional to laboratory-enumerated counts, but systematic biases in the diver estimates can be accounted for by vegetation type and density (Biggs and Funk 1988, Biggs In Press). Individual diver effects were not significant in the 1988 and 1989 survey, but potential differences among individual divers will be examined. The basic form of models used to account for biases in diver observations is:

$$Y_{ijk} = e^{\alpha} \cdot e^{D_j} \cdot e^{V_k} \cdot X_{ijk}^{\beta_{jk}} \cdot e^{\epsilon}, \text{ where} \qquad (7)$$

α = a constant;
D_j = parameters representing the effect of j^{th} diver;
V_k = parameters representing the effect of the k^{th} vegetation type;
β_{jk} = parameters controlling the functional form of the relationship between the diver estimate and laboratory-enumerated egg count for diver j in vegetation type k;
Y_{ijk} = the i^{th} laboratory egg count in the vegetation-diver stratum jk;
X_{ijk} = the i^{th} diver estimate in vegetation-diver stratum jk; and
ϵ = a normally distributed random variable with mean 0 and variance σ^2.

A multiplicative-effect model is chosen because relative estimation errors are expected to change with egg density. The distribution of laboratory-enumerated egg counts for a given diver estimate was positively skewed in the 1988 and 1989 surveys (Biggs and Funk 1988, Biggs In Press), so that the logarithmic transformation used to estimate the parameters of the multiplicative-effect model also stabilized the variance and corrected the skewness of the egg density estimates. After a logarithmic transformation model 7 becomes:

$$\log_e(Y_{ijk}) \quad = \quad \alpha + D_j + V_k + \beta_{jk} \cdot \log_e(X_{ijk}) + \epsilon \tag{8}$$

β_{jk} = the slope of the relationship between the logarithm of the diver estimate and the logarithm of the laboratory-enumerated egg count.

In logarithmic form, the model comprises a linear analysis of covariance problem with two factor effects (vegetation and diver) and 1 covariate (diver-estimated egg number). The SAS Institute Inc. (1987) procedure for general linear models will be used to obtain least squares estimates of parameters and evaluate variance components. In addition to the two factor effects and one covariate, terms for diver-vegetation group interactions, density-vegetation group interactions and density-diver interactions will be considered in the analysis of covariance. Three-way and higher level interaction effects will not be considered because the objective is to derive a simple model with a relatively small number of parameters. Backward stepwise procedures will be used to determine subsets of the six effects that explain the maximum amount of variability in the data with the smallest number of parameters. During the backward stepwise procedures, effects will be included or eliminated from the model based on the probability level of F ratios for partial sums of squares.

Translation of the predicted values from the logarithmic model, equation (8), back to the original scale, equation (7), requires a correction for bias. The bias in the expected value of Y_{ijk} is $\exp(\frac{1}{2}\sigma^2)$ when the true variance of $Y_{ij}k$, σ^2, is known. Laurent (1963) gives an exact expression for the bias correction that incorporates additional terms when σ^2 is estimated from a sample. For the diver calibration data, the biases in estimating σ^2 from a sample were less than 0.05% (Biggs and Funk 1988), so expected values for Y_{ijk} are estimated from:

$$E(Y_{ijk}) \quad = \quad e^{\alpha} \cdot e^{D_j} \cdot e^{V_k} \cdot X_{ijk}^{\beta_{jk}} \cdot e^{\frac{1}{2}s^2}, \text{ where} \tag{9}$$

s = the mean squared error from the general linear model.

The variance of individual predicted Y_{ijk} is estimated from:

$$Var(Y_{ijk}) = [e^{(2Y_{ijk} + \sigma^2)}] \cdot [e^{\sigma^2} - 1] . \qquad (10)$$

Although the above expression is appropriate when σ is known (Laurent 1963), s will assumed to be an unbiased estimate of σ for the 1990 study since only a small bias was introduced into estimates of the mean when s was used to estimate σ in past years (Biggs and Funk 1988).

Spawning Biomass per Billion Eggs (B')

Catch sampling programs will be used to estimate the relationship between spawning biomass and egg deposition. The tonnes of spawning biomass required to produce one billion eggs (B') will be estimated as:

$$B' = \frac{\bar{W} \cdot S}{F(\bar{W}_f)} \cdot 10^3 \quad , \text{ where} \qquad (11)$$

$\bar{W}$ = estimated average weight in grams of all herring (male and female) in the spawning population in an area;

S = estimated ratio of total spawning biomass (male and female) to female spawning biomass;

$F(\bar{W}_f)$ = estimated fecundity at the average weight of females in the spawning population in an area, in numbers of eggs; and

10^3 = units conversion factor = $\dfrac{10^{-6}}{10^{-9}} = \dfrac{\text{conversion from grams to tonnes}}{\text{conversion from eggs to billions}}$.

Estimates of average weight, sex ratios, and fecundies are not independent. The variance of B' is approximately:

$$\begin{aligned} Var(B') = (10^3)^2 \{ & [S/F(\bar{W}_f)]^2 \, Var(\bar{W}) \\ & + [\bar{W}/F(\bar{W}_f)]^2 \, Var(S) \\ & + [\bar{W}S/F(\bar{W}_f)^2]^2 \, Var(F(\bar{W}_f)) \\ & + 2Cov(\bar{W},S) \, [S/F(\bar{W}_f)] \, [\bar{W}/F(\bar{W}_f)] \end{aligned}$$

$$- 2Cov[\overline{W},F(\overline{W}_f)]\ [S/F(\overline{W}_f)]\ [\overline{W}S/F(\overline{W}_f)^2]$$

$$- 2Cov[S,F(\overline{W}_f)]\ [\overline{W}/F(\overline{W}_f)]\ [\overline{W}S/F(W_f)^2]\ \}. \qquad (12)$$

The covariance terms containing S, $Cov(\overline{W},S)$ and $Cov[S,F(\overline{W}_f)]$, will not be included in the estimate for 1990. These terms were not included in the estimate of Var(B') in 1988 and 1989 because S was estimated from either the same pooled AWL samples or from a single AWL sample. However, $Cov(\overline{W},S)$ and $Cov[S,F(\overline{W}_f)]$ probably contribute a small amount to Var(B') since the term involving $Cov[\overline{W},F(\overline{W}_f)]$ was very small in 1988 and 1989.

Correction for Egg Loss

The only component needed for the biomass estimate that has not been estimated within the present study is egg loss (the proportion of eggs disappearing from spawning areas between the time of spawning and the time of surveys). Before the extensive use of SCUBA diving to survey herring egg deposition, estimates of egg loss were relatively high. Montgomery (1958) estimated that egg loss was 25 to 40% for Southeast Alaska, and Blankenbeckler and Larson (1987) used similar estimates in their early egg deposition surveys in Southeast Alaska. However, Haegele et al. (1981), counducting diving surveys in British Columbia, argued that egg loss was only about 10%. They based this assumption on the fact that most spawn was deposited in the subtidal zone where egg loss, primarily due to predation and wave loss, was probably less than had been observed in the intertidal zone. Presently, egg loss is assumed to be 10% in British Columbia, Southeast Alaska and PWS since the timing of diving surveys in relation to spawning has been standardized among these areas (W. Blankbeckler, ADF&G, Ketchican, personal communication; Biggs and Funk 1988). To test this assumption, an initial study of actual egg loss within PWS will be conducted in conjunction with the egg survival study during 1990.

Herring Age, Weight, Length, Growth and Fecundity Estimation

Mean Weight and Sex Ratio

Mean weight and sex ratio will be estimated from AWL samples collected from the commercial catch and ADF&G test fishing conducted before or after commercial openings. AWL samples will be collected from the spawning population in each of the spawn deposition summary areas (Southeast, Valdez Arm, North Shore, Naked Island, and Montague Island). The approximate timing of peak herring spawning in each summary area will be determined from aerial survey sightings of milt and herring schools. All herring AWL samples taken during the time of peak spawning in each area will be pooled to obtain estimates of mean weight and sex ratio for each summary area. Average weights and sex ratios for all of PWS will be estimated as the average of the estimates from each of the areas weighing by the spawn deposition biomass estimate in each area.

The estimated sex ratio, S, is expressed as the ratio of the number of herring of both sexes in the AWL samples to the number of females. The binomial distribution will be used to estimate the proportion of females, p, in samples, where S = 1/p. The variance of S is then given by:

$$\mathrm{Var}(S) = \frac{S^2(S-1)}{n}, \tag{13}$$

where n is the number of herring in the AWL sample.

EGG LOSS

Commercial and test fishing catches will be sampled for AWL, fecundity, and roe maturity information. These data are used to estimate spawning biomass and spawn deposition, forecast herring returns, and evaluate effects of the oil spill on survival. Information on fecundity, average weight of females, and sex ratio are also important components of the spawn deposition biomass estimator. AWL sampling will be intensified in 1990 to increase the precision of biomass estimates and, therefore, enhance the possibility of detecting oil spill impacts upon herring stocks.

Sampling will begin as soon as concentrations of herring appear in near shore areas that can be sampled with purse seine gear. Efforts will be made to sample major concentrations of herring throughout PWS at periodic intervals throughout the spawning period. The major objective of this portion of the study will be to determine the age, sex, and size composition of all major herring concentrations in the general areas of Valdez Arm and the Eastern District, the North Shore, Naked Island, and Montague Island. Results of the aerial survey program will be used to direct test fishing efforts within each area.

Each week during the sampling period, early April through early May, six to eight samples of herring will be collected through test fishing or from the commercial catch. A sample of 403 herring is needed to simultaneously estimate the proportion of at age of a multinomial population such that 95% of the time the estimated proportions will be within ±10% of the true proportions (Thompson 1987). Therefore, efforts will be made to obtain samples consisting of approximately 450 herring to allow for the occurrence of unreadable scales (usually less than 5% of the sample). Herring samples will be flown from the fishing grounds each day to Cordova for processing. Augmentation of the standard AWL sampling program will be needed to collect sufficient samples for hydrocarbon analyses, fecundity estimates, and oocyte loss measurements. All AWL data will be collected using personnel and funding from the standard (i.e. non-oil spill related) AWL sampling program conducted by ADF&G within PWS.

The following data will be collected for each herring sampled:

1. sex (determined by examination of gonads);
2. standard length (in mm);
3. weight (in grams);
4. age (determined by examination of scales);
5. capture information (date of capture, fishing district, subdistrict,local name for the location, fishing vessel name, gear type);
6. herring number on data form; and
7. data form number.

Fecundity

Additionally, a subsample of herring will be collected to estimate fecundity. The average fecundity at the average female weight (F(Wf)) from expression (11) is a component of the spawn deposition survey biomass estimator. The spawn deposition survey attempts to estimate spawning biomass so that the 95% confidence interval is within ± 25% of the actual biomass estimate. If fecundity sampling is to contribute no more than 1% to the confidence interval width, a sample of 85 females of exactly the average weight of females in the spawning population is needed. Since average female weight is unknown at the time of sampling, more herring must be sampled over a range of sizes. Based on the precision of 1989 fecundity sampling, a sample size of 130 herring would be needed to provide the desired level of precision. An additional 100 samples clustered around the average size of females in 1989 will be taken to compare with the past year's data. The average weight of a female in the fecundity sample in 1989 was 119 grams. The predicted average weight for the population in 1990 is 142 grams that translates to an average predicted length of 215 to 225 mm. Therefore, sampling should be clustered about the 210 mm to 230 mm length classes is desirable.

Effects of the oil spill on fecundity will also be examined by testing for differences in fecundity among five areas: (1) Southeast Shore including Simpson and Sheep Bays, Port Gravina, and Port Fidalgo; (2) Northeast Shore including

Valdez Arm and Tatitlek Narrows; (3) North Shore; (4) Naked Island; and (5) Montague Island. While extensive mortality of adult herring from the oil spill has not been documented, it is possible that sublethal stresses could result in reduced fecundity.

Herring fecundity samples will be collected concurrently with AWL samples. To accomplish this, at least five individual test purse samples will be subsampled. Females within these purse seine samples will be randomly selected within 10 mm length classes until stratum goals are reached. The roe sacs from each selected females herring will be removed and placed in a ziploc bag labeled with the AWL number corresponding to that female. Each individually packaged roe sample will then be placed in a larger plastic bag labeled with the sample date and location. Standard laboratory procedures have been developed to process fecundity samples.

Samples for hydrocarbon analyses will also be obtained from herring collected at each of the four locations (Naked Island, Galena Bay, Cedar Bay, and Stockdale Harbor):

1. three gut samples for hydrocarbons;
2. three viscera samples for hydrocarbons;
3. three muscle samples for hydrocarbons; and
4. three gonad samples for hydrocarbons.

General observations on the prevalence of nematodes, liver and gall bladder condition, and fullness of gut will also be made for each herring collected for hydrocarbon analyses. Standard protocol, including sample sizes and collection strata, for collecting herring eggs for hydrocarbon analyses will be followed.

In addition to the 500 ovaries collected for fecundity analysis, 50 ovaries will be collected and preserved in a buffered formalin solution for oocyte loss measurements. An additional 25 preserved ovaries will be obtained from Sitka Sound, Southeastern Alaska, for use as a control. Atretic eggs and histopathological damage in the sac roe of the adult herring will be recorded during oocyte loss observations.

A linear relationship was found between fecundity and weight for herring samples collected in 1988 and 1989 (Biggs and Funk 1988). In 1990, the fecundity-weight relationship will again be examined using data pooled across all areas. Average fecundity for each area will be estimated from the fecundity-weight relationship using the average female weight from each area. The average fecundity for each area will then be applied to the spawn deposition biomass estimator ($F(\overline{W}_f)$ in expression (11). The variance of estimated average fecundities will be approximated using the variance of predicted means from the fecundity-weight linear regression (Draper and Smith 1981):

$$\mathrm{Var}[F(\overline{W}_f)] = s_2\left[\frac{1}{n} + \frac{\quad}{q} + \frac{(W_f - \overline{WF})^2}{\Sigma(W_i - WF)^2}\right], \text{ where} \qquad (14)$$

s^2 = residual mean square from the fecundity-weight linear regression;
$\overline{W}_f$ = average weight of female fish in the spawning population;
$\overline{WF}$ = average weight of females in the fecundity sample;
W_i = weight of individual females in the fecundity sample;
n = total number of females in the fecundity sample; and
q = total number of females in the AWL sample.

General Linear Model (GLM) extensions of linear ANOVA techniques will be used to test for year and area effects in growth and fecundity.

Herring Egg Survival and Egg Loss Estimation

Oil contamination of herring spawning sites and exposure of spawning herring to oil may cause mortality to herring eggs, decrease hatching success, reduce larval viability, and impair larval growth. The major objective of this portion of the study will be to measure immediate, easily observable mortality of herring eggs in a subsample of the sites used in 1989. In 1990, nine sites will be used to conduct the egg loss study, collect hydrocarbon samples, collect live eggs for the laboratory portion of the study, and to gather samples for sublethal impact testing.

Three study transects will be re-established in each of three areas used during 1989 (assuming those areas receive spawn in 1990): Naked Island, Fairmont Bay, and Rocky Bay on North Montague Island. The ratio of live to dead eggs will be determined along each transect from subsamples of 100 eggs. Dead eggs turn an opaque white color and are easily identified with low power magnification under a binocular microscope. Mussel tissue samples will also be collected for hydrocarbon analysis.

A 1990 laboratory egg incubation experiment, similar to the one conducted in 1989, will be carried out by a private consultant contracted by ADF&G. This experiment will determine the survival of herring eggs and larvae collected from the nine study sites in PWS and three control sites in Sitka Sound, Southeast Alaska.

Divers will establish the location of mean low water (MLLW) at the start of each dive. Each dive team will attempt to sample three transects each day. Each transect will be sampled every two days until most herring eggs have hatched (about 20 May). A total of twelve to sixteen dives will be made along each transect over the course of egg development.

The location of each transect will be marked. Divers will work along transects by following a compass course set perpendicular to shore. During the first dive, five sample stations at the +1, 0, -5, -15, and -30 foot depths will be marked underwater with weighted floats anchored by a spike. Station depths, corrected for tide stage, will be determined using diver's depth gauges. Three samples of vegetation containing at least 100 eggs will be collected at each depth along the transect whenever possible.

The following data will be recorded the first time each transect is sampled:

1. transect number;
2. site description (location, exposure, plant community);
3. number of depth strata from which herring eggs were obtained; and,
4. original treatment category (high, medium, low, or no oil-impact).

The following data will be recorded every time each transect is sampled:

1. transect number and location
2. date;
3. dive time;
4. treatment level;
5. air and water temperature;
6. maximum depth; and,
7. number of live, dead, and other eggs per sample.

Herring eggs and mussels will be collected at each site for hydrocarbon analysis on the first day. Three samples each of eggs and mussels (six per transect) will be collected from each sampling location, including the three control sites in Sitka Sound, at the lowest tide stage at which mussels occur (usually about 5 ft below MLLW). Collection methods will follow established protocol, including chain of custody forms.

During one of the sampling trips to each transect, herring eggs and associated vegetation will be collected for the laboratory incubation project. Herring eggs will be collected at nine sites within Prince William Sound and three sites within Sitka Sound. At each site, three samples of vegetation containing at least 300 eggs will be collected at three depths (MLLW, -5 ft, and -15).

Herring eggs will also be collected and preserved in a phosphate buffered formalin solution, using sea water, for biochemical analysis. Results of these analyses may help determine the extent of oil exposure from determination of sublethal effects.

Finally, herring egg samples will be collected from each of the 12 study sites for cytogenetic analysis. Ten egg patches consisting of approximately 1000 eggs each (5 ml) will be preserved in a buffered formalin solution from each study site (i.e. a total of 120 samples). A subsample of eggs will be taken from each sample jar and analyzed for mitotic aberrations in the embryonic and yolk cells. Detailed methodology will be provided by the lab contracted to perform the service.

Egg survival data will be summarized by level of hydrocarbon impact, transect, depth, date of sample collection, and proportion of live eggs. Several different analyses will be conducted to test for differences in egg survival due to the level or amount of oil. The first analysis will be a nested mixed factor ANOVA incorporating all possible factors and interaction effects like:

$$Y_{ijkl} = u + A_i + B_j(A_i) + C_k + D_l + AC_{lk} + AD_{il} + CD_{kl} + ACD_{ikl} + \epsilon_{ijkl}, \quad (15)$$

where,

Y_{ijkl} = the arc sin transformed proportion of live eggs;
u = grand mean;
A_i = oil impact level (treatment; fixed effect);
B_j = transect (random effect; nested within treatment);
C_k = depth (fixed effect);
D_l = time interval (days) between spawning and sample collection (random effect);
$AC_{lk} + AD_{il} + CD_{kl} + ACD_{ikl}$ = interaction terms; and
ϵ_{ijkl} = error terms, which, after arsine transformation are assumed to be normally distributed with mean 0 and variance $o.^2$

The second analysis will be an analysis of covariance (ANCOVA) where both treatment (A_i) and time (D_l) will be treated as covariates. Treatment and depth will be treated as fixed effects, while transect (nested within treatments) and time will be treated as random effects. This model will describe the decrease in the proportion of live eggs over time, using time as a covariate, and will reduce the number of parameters that must estimated for the model.

Egg loss is the only component of the spawn deposition biomass estimator that has not been measured. In the past, a 10% egg loss factor was applied to all transect data to adjust the total spawned biomass estimate. In 1990 a preliminary egg loss study will be conducted in conjunction with the egg survival study to determine whether the 10% egg loss factor is appropriate for use at PWS study locations.

The same three transects used in each of three areas for the egg survival study will be used in the egg loss study: Naked Island, Fairmont Bay, and Rocky Bay on North Montague Island. Egg loss will be estimated by observing changes in egg density over time at these locations.

To avoid sampler bias in selecting samples, as was done for the egg survival study, a marked leadline, 20 m or less in length, will be used to select samples. The leadline will be placed parallel to shore and to the left of each transect station. Egg density estimates will be taken within 0.1 m^2 sample quadrants using the same procedures described for spawn deposition diver transects. For each transect, five egg density estimates will be made at each of five depths (+1, 0, -5,-15,-30) ft depths). Divers making egg density estimates for the egg loss study will be calibrated in a similar manner used for divers assisting in spawn deposition surveys. One egg count calibration sample will be collected at each transect and at each depth level. For the calibration sample, all herring eggs and vegetation will be removed from a 0.1 m^2 sample quadrant. Counts of eggs within the calibration sample will be made in the laboratory at a later time. Egg density estimates and egg counts will be conducted every other day from the time of spawning in each area until the time of hatching (a period of approximately 20-25 days). It should be possible to obtain egg density estimates and egg counts for about eight days during the study. This would result in a total of approximately 1,800 egg density estimates (three areas; 3 transects per area; five depths per transect; five egg density estimates per depth; eight days) and 540 egg counts (three areas; three transects per area; five depths per transect; one egg count per depth; eight days) for the season.

Egg loss data will be summarized by area, transect, depth, date of sample collection, and estimated egg density. Egg density estimates will be adjusted for observer (diver) biases, following procedures set forth for diver calibration in the spawn deposition survey, prior to analyses. The change in egg density over time for each transect and depth will be examined.

BIBLIOGRAPHY

Biggs, E.D., and F. Funk. 1988. Pacific herring spawning ground surveys for Prince William Sound, 1988, with historic overview. Regional Information Report 2C88-07, Alaska Department of Fish and Game, Anchorage, 73 p.

Blankenbeckler, W.D. and R. Larson. 1982. Pacific herring (Clupea harengus pallasi) spawning ground research in Southeastern Alaska, 1978, 1979, and 1980. Alaska Department of Fish and Game Technical Report No. 69. 51 p.

Blankenbeckler, W.D. and R. Larson. 1987. Pacific herring (Clupea harengus pallasi) harvest statistics, hydroacoustical surveys, age, weight, and length analysis, and spawning ground surveys for Southeastern Alaska, 1980-1983. Alaska Department of Fish and Game Technical Data Report No. 202. 121 p.

Cochran, W.G. 1963. Sampling techniques. John Wiley and sons, New York.

Draper, N.R. and H. Smith. 1981. Applied regression analysis. John Wiley and Sons, New York.

Goodman, L.A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Haegele, C.W., R.D. Humphreys, and A.S. Hourston. 1981. Distribution of eggs by depth and vegetation type in Pacific herring (Clupea harengus pallasi) spawnings in Southern British Columbia. Canadian Journal of Fisheries Aquatic Sciences 38:381-386.

Hourston, A.S., H. Rosenthal, and H. von Westernhagen. 1984. Viable hatch from eggs of Pacific herring (Clupea harengus pallasi) deposited at different intensities on a variety of substrates. Canadian Technical Report of Fisheries and Aquatic Sciences 1274.

Jackson, M. and R.C. Randall. 1983. Herring spawn deposition surveys in Prince William Sound, 1983. Alaska Department of Fish and Game, Prince William Sound Data Report No. 83-6. 15 p.

Jackson, M. and R.C. Randall. 1984. Herring spawn deposition surveys, Prince William Sound, 1984. Alaska Department of Fish and Game, Prince William Sound Data Report 84-16. 15 p.

Laurent, A.G. 1963. Lognormal distribution and the translation method: description and estimation problems. Journal of the American Statistical Association 58:231-235.

Montgomery, D.T. 1958. Herring spawning surveys if Southeastern Alaska. United States Fish and Wildlife Service, Bureau of Commercial Fisheries, Marine Fisheries Investigations Field Operations Report. 22 p.

Palsson, W.A. 1984. Egg mortality upon natural and artificial substrata within Washington State spawning grounds of Pacific herring (Clupea harengus pallasi), M.S. Thesis, University of

Washington, Seattle.

SAS Institute Inc. 1987. SAS/STAT Guide for personal computers, version 6 edition. SAS Institute, Cary, North Carolina.

Schweigert, J.F., C.W. Haegele, and M. Stocker. 1985. Optimizing sampling design for herring spawn surveys on the Strait of Georgia, B.C. Canadian Journal of Fisheries and Aquatic Sciences 42:1806-1814.

Thompson, S.K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41:42-46.

BUDGET: ADF&G

Salaries	$ 121.7
Travel	6.9
Contracts	398.0
Supplies	16.8
Equipment	15.0
Total	$ 558.4

FISH/SHELLFISH STUDY NUMBER 13

Study Title: Effects of Hydrocarbons on Bivalves

Lead Agency: ADF&G

INTRODUCTION

Bivalve mollusks are an important component of the food chain, existing as prey for bear and sea otters, and bivalves support subsistence and sport fisheries in PWS. Because they are relatively sedentary and occupy nearshore areas, bivalves may be particularly susceptible to contamination by oil. In contrast to finfish species which metabolize hydrocarbons at a much higher rate, bivalves metabolize hydrocarbons at a reduced rate and are therefore much more likely to bioaccumulate hydrocarbons. It is hypothesized that increased hydrocarbons in nearshore sediments could affect bivalves for a long period of time by increasing mortality, decreasing growth, or causing sublethal injuries. The effects of oil on the growth and survival of littleneck clam (Protothaca staminea) in particular and other bivalves in general have been well documented (Anderson et al. 1982, Anderson et al. 1983, Augenfeld et al. 1980, Dow 1975, Dow 1978, Keck et al. 1978).

This study seeks to continue to evaluate the potential effects caused by the oil spill by comparing data obtained from several beaches representing different levels of oil contamination. The effects of the mechanical cleaning of beaches following the spill will also be evaluated. Documenting effects on littleneck clams, butter clams (Saxidomus giganteus), and razor clams (Siliqua patula) is required to determine the scope of impact by the oil spill on these species, associated ecosystem elements, and current and future employment, recreation, and lifestyles of coastal communities on PWS.

OBJECTIVES

A. Test if the level of hydrocarbons in bivalves and in sediments is not related to the level of oil contamination of a beach.

B. Document the presence and type of damage to tissues and vital organs of bivalves sampled from beaches such that differences of ±5% can be determined between impact levels 95% of the time.

C. Test if the growth rate of littleneck, butter and razor clams is the same at beaches of no oil impact, intermediate or high levels of oil impact and intermediate or high levels of oil impact in areas which had been treated.

D. Test if the proportion of dead clams is not related to the level of oil contamination or treatment at a beach.

E. Document numbers of young-of-the-year clams and test if the proportion of young-of-the-year clams is not related to the level of oil contamination or treatment at a beach.

METHODS

This study will be conducted by the ADF&G and represents a consolidation of the former F/S Studies 13 and 21. During April through June, 1990, beaches will be selected which, if possible, coincide with those sampled during 1989. An emphasis will be placed on beaches that are known to be important habitat for bear or sea otters. It is possible that the baseline beaches sampled in 1989 will not be resampled because they do not constitute bear and/or otter habitat. Sites will be chosen inside PWS which have not been impacted by oil, which have received moderate to heavy oiling, and which have been cleaned of oil by mechanical means. Sites outside of PWS will be chosen which have not been impacted by oil and which have received heavy to moderate oiling. Because razor clams are not found in the same habitat as butter or littleneck clams, razor clam beaches along the Kenai and Alaska peninsulas will be located which were affected and unaffected by oil.

Beaches of known bear and/or sea otter habitat and known to contain clams will be classified by oil contamination levels. Nine study sites for littleneck or butter clams in PWS representing three levels of oil contamination (subjectively rated as no contamination, intermediate or high contamination and intermediate or high contamination which had been treated by mechanical means) will be sampled. Beaches with no oil contamination are Hell's Hole, Double Bay, and Simpson Bay. Beaches with moderate or heavy oil contamination which have been treated or untreated include Gibbon Anchorage, Snug Harbor, Wilson Bay, North Chenega Island, Horseshoe Bay and Green Island. Sites not sampled in 1989 are selected contingent upon habitat suitability.

Since cleaning efforts were not as intense outside of PWS, and since a smaller number of sites have been chosen there, the additional sample level based on mechanical treatment will not be investigated outside of PWS. Eight study sites for littleneck or butter clams representing two levels of oil contamination (subjectively rated as no contamination or moderate to high contamination) were chosen to be sampled in the Lower Cook Inlet and Kodiak areas. Beaches with no oil contamination are Jakalof Bay, Kachemak Bay and Seldovia Bay in lower Cook Inlet and Port Bailey on Kodiak Island. Beaches with moderate to heavy oil contamination are Windy Bay, Tonsina Bay and Port Dick in Lower Cook Inlet and Kupreanof Strait on Kodiak Island.

Six sites have been chosen for sampling razor clam habitat representing two levels of oil contamination (subjectively rated as no or high contamination). Beaches with no oil contamination are

Halibut Bay, Polly Creek and Augustine. Beaches with moderate or heavy oil contamination are Swishak, Alinchak and South Nuka Island.

For each sample site, the following site description information will be recorded: site orientation (N-NW etc.), latitude, longitude, beach slope, low tide height, percent dominant substrate composition, temperature and salinity of the water, weather and wave action. Temperature and salinity of the water will be measured at a distance of approximately 5 meters offshore from the sampled beach at the daily low slack tide.

Beaches will be sampled for littleneck and butter clams at maximum low tides for a monthly tidal cycle. For beaches which had been sampled in 1989, 1990 tidal heights and time of year will be matched with the 1989 values as closely as possible. At each beach, three sampling transects will be run to insure complete coverage of the beaches as distribution of oil on the beaches is unknown. Transects will be perpendicular to the water's edge and parallel to each other with a total distance between each transect of 15 meters. Transects are perpendicular to the water to insure complete sampling of clam habitat. The top of each transect is placed at the +1.6 meter tide level and the bottom of the transect at the lowest tide level.

Prior to sampling, the upper distribution of clams will be determined by removing sediment to a depth of 30 cm (12 in) along a trench adjacent to the proposed transect. The trench is dug starting from the top of the transect and continuing until clams are encountered.

A total of eight quadrants will be sampled from each transect to obtain hydrocarbon and necropsy specimens. Sample quadrants are each 0.25 m^2 (0.5 m by 0.5 m). Additional sampling or complete sampling of each transect (all possible sampling quadrants) may be necessary if insufficient numbers of clams are recovered within the eight sampling quadrants to meet project objectives. Quadrants will be sampled from the top to the bottom of each transect as the tide recedes. The distribution of clams will extend below the low tide levels encountered during each sampling event. However, the bottom of each transect and the bottom sampling quadrant will occur at the daily low tide level. The upper layer of sediment will be removed and washed through a 1 mm mesh screen to retain small young-of-the-year clams. The remainder of the sediment is washed through a larger 3 mm mesh screen.

Razor clam habitat tends to be comprised of long and broad sandy beaches. Because of the size of the area inhabited by razor clams, and due to the time and manpower required for a full scale study of this species, there will be no attempt made to estimate the abundance of razor clams on the beaches being surveyed. The primary objectives of this portion of the study are to obtain hydrocarbon and necropsy samples, and to collect a sufficient number of razor clams for age and growth determination.

Razor clams inhabitat the 0.91 m to -1.22 m tidal range (Quinn and Jones, 1989). In order to minimize sampling effort, a tidal height known to contain a large number of clams will be established at approximately 0 m to -0.33 m on each beach. A transect along this tidal height will be dug with a high pressure pump (pre-emergent fry pump) until the desired sample size has been collected.

A total of nine sediment samples will be collected from each beach site (triplicates from each transect). All sediment samples will be collected before bivalve sampling is performed. The triplicate hydrocarbon samples from each transect will be composite sediment samples which will be collected by scooping one tablespoon (15 cc) of sediment to a depth of 2 to 3 cm from each of the eight sample quadrants on a transect.

All samples from each transect will be placed in 8 oz glass jars rinsed with methylene chloride. Each jar will be labelled with the site name, latitude, longitude, date, "SEDIMENT", transect number, sample number, names of the sampling team members, "BIVALVE", and "ADF&G". Data will be recorded on the appropriate form.

Triplicate composite sediment samples will be taken from the razor clam beach transect. This will provide 3 samples per beach and 9 samples per treatment level.

The small sub-samples of sediment taken from each sampling quadrant will provide a representative mixture of sediment composition and contamination throughout the transect. Three composite sediment samples for each transect at each site provides 27 composite samples for each impact level (no, intermediate or high, and intermediate or high with treatment). The industry standard is 8 samples for each treatment level. A sample size of nine composite samples is considered an adequate number of samples to detect a difference in sediment contamination between impact levels at the desired α and β levels. This coverage level is being tripled.

Three common species of clam, littleneck clam Protothaca staminea, butter clam Saxidomus giganteus, and razor clam Siliqua patula will be sampled for hydrocarbon analysis, necropsy, and age and growth statistics.

Specimens for hydrocarbon analysis will be taken from each sampling quadrant before any other specimen sampling is conducted. Bivalves of each species will be randomly selected for hydrocarbon analysis from sampling quadrants at each site.

One hydrocarbon sample for each species will be obtained from each transect. For littleneck clams and butter clams, each hydrocarbon sample will be composed of 14 specimens. The 14 specimens from each transect (1 hydrocarbon sample) will be selected by randomly picking two clams with a shell length of 2-5 cm from each of the eight sampling quadrants and discarding two clams selected at random.

Each hydrocarbon sample for razor clams will optimally be composed of six to eight individuals. Six to eight razor clams with a shell length of 2-5 cm will be randomly collected at the beginning, middle and end of the collection transect, for a total of three samples per site.

Bivalve samples are being limited to a particular size range because rates of uptake, metabolism, and depuration by clams probably change with size. If specimens of the desired size are not found in each of the sampling quadrants, then the desired number of additional specimens will be collected from the other sample quadrants.

Combined tissue samples from each sampling quadrant will provide a representative mixture of bivalve tissue composition and contamination throughout the transect. The desired size of each composite tissue sample is 15 gm. The number of bivalves to provide this sample from each transect was estimated based on the average size of individuals of each species. An estimate of three hydrocarbon samples from each site is needed for detecting contamination between impact levels. A sample size of nine composite samples per three impact levels within the sound will allow the detection of differences in hydrocarbon content of 1.9 standard deviations with α and β levels of 0.05 and 0.1, respectively. A sample size of 12 composite samples per two impact levels outside of the sound will allow the detection of differences in hydrocarbon content of 1.4 standard deviations with α and β levels of 0.05 and 0.1, respectively.

Collection of specimens for necropsy will begin only after all hydrocarbon samples have been taken. Total sample size is 20 live or moribund specimens of each species taken at random from each beach site. Noticeable numbers of moribund animals will be documented and sampled separately. With 20 bivalves sampled from each beach, the total sample for each treatment (no, intermediate or high oil contamination, and intermediate or high oil contamination which has been treated) will be 60 within the sound and 80 for each of two treatment levels (oiled and not oiled) outside the sound. This sample size will allow detection of differences in presence of tissue damage of ±5% with 95% confidence between samples obtained from beaches with different levels of oil impact. This sample size will allow detection of gross differences between beaches with no, medium or high oil impact and medium or high oil impact which have been treated by mechanical means.

One specimen of each species will be randomly selected from each sampling quadrant. This will yield a total of 24 specimens. Four specimens from the 24 collected will be randomly selected and discarded from the sample to achieve a sample size of 20 specimens. Twenty razor clams will be collected at random along the beach sampling transect.

For littleneck and butter clams, a total of 100 specimens will be collected from each transect at each site. From each transect six sampling quadrants will be selected at random. From each of these, 12 specimens will be randomly sampled from the quadrant containers. Fourteen specimens will be randomly sampled from the remaining two quadrant containers.

The sample of 100 specimens per species from each transect will provide 300 samples from each beach or 900 and 1,200 clams per species for each level of beach impact inside and outside of PWS, respectively. Sample size for growth is based on the difference between mean shell height (width) for age i and age i+1 clams, variance in shell height for age i+1 clams, probability of making a type I error equal to .01 and probability of making a type II error equal to .05 (Netter and Wasserman 1985). Data for mean shell height and variance in shell height was taken from Paul and Feder (1973) for littleneck clams and Nickerson (1977) for butter clams. Sample size for detecting difference in growth at age of clams between impact levels was estimated at 261-275 littleneck clams for each impact level. This sample size was rounded up to 300 clams. The purpose of 3 sites for each impact level is to provide replicates at each impact level. The sample size required for detecting difference in growth at age was somewhat smaller for butter clams, however because not all size ranges were represented in the available data, the larger sample size of 300 clams was recommended for this species as well.

All shells will be collected from each quadrant and the number of live clams, the number of dead hinged shells, and the number of half shells will be recorded. One hundred hinged shells from dead clams taken in the sampling quadrant located at the median tidal height (quadrant 4) will be retained for age analysis. If possible, some will have the microstructure analyzed to determine the year of death. If less than 100 hinged shells are found in the three mid-tidal height sampling quadrants, additional shells will be collected at random at this approximate tidal height until the sampling objective of 100 dead shells is obtained.

The sample size for determining the age composition of razor clams is based on data taken from Clam Gulch (Quinn and Jones, 1989). Quinn and Jones recommend a sample size for determining age composition of between 300 and 400 clams per stratum of interest. A minimum of 300 razor clams per beach will be collected for size and age determination.

A total of 600 clams will be submitted for microstructure analysis. A random sample of 200 clams collected from each of three representative beaches (no contamination, intermediate or high oil contamination, and intermediate or high oil contamination which has been treated) located within PWS will be analyzed. In particular, this analysis will look for the presence of a "check" in the shell material which has been laid down by clams as a possible response to the oil spill. Growth which has occurred since the "check" will be examined. Growth rates will be reported as well as estimated ages.

To further quantify oil impacts on clam growth and to discount site effects, littleneck clams will be transplanted from oiled to non-oiled areas and from non-oiled to oiled areas. Three oiled beaches and three non-oiled beaches will be chosen for this purpose. Criteria for selecting paired oiled/non-oiled beaches, to the extent possible, will include similarity in profile, drainage and length-frequency distribution of bivalves.

Two tidal heights will be selected, each of which has an adequate number of specimens at paired beaches. Clams will be transplanted to the same tidal height from which they originated. At each tidal height, three locations will be established creating triplicate sampling stations at each height. Each location will consist of three adjacent clearly marked 0.25 m^2 plots. One plot will be marked, but will not be disturbed until clams are sampled for growth. Another plot will be dug to a depth of 0.3 m and all of the removed clams and sediment will be replaced in the plot. Clams from this plot will have a small notch filed into the ventral edge of the valves to mark the time of disturbance. All clams will be removed from the third plot which will be dug to a depth of 0.3 m and the transplanted clams will be placed in this plot along with the original sediment. The clams which have been removed will be collected for comparison with the clams in the undisturbed plots at the end of the experiment.

Clams to be transplanted will be obtained by digging a trench along the prescribed tidal height of the donor beach until 150 clams between 15 mm and 35 mm in length have been collected. Fifteen millimeters is considered to be the smallest size which can effectively be tagged. Clams less than 35 mm are selected to narrow the range of ages for which differences in growth are being determined and because the maximum growth rate appears to occur within this size range. A sample of 50 specimens from each of three plots will provide 150 samples from each tidal height at each beach and 450 clams for each tidal height and level of beach impact. Sample size for growth is based on the difference between mean shell height for age i and age i+1 clams, variance in shell height for age i+1 clams, probability of making a type I error equal to .01 and probability of making a type II error equal to .05 (Netter and Wasserman 1985). The sample size was determined after comparing data for mean shell height and variance in shell height taken from Paul and Feder (1973) and Nickerson (1977). The sample size for detecting between impact level differences in growth at age of clams in the size range of 15 mm to 35 mm was estimated at 133 clams from the Paul and Feder data and at 85 clams from the Nickerson data for each impact level. The higher estimate was rounded up to 150 clams by including the next smaller size group (age 5-6). The purpose of 3 sites for each impact level is to provide replicates at each impact level.

Transplanted clams will be identified by marking each clam with a numbered floy tag secured with a quick-drying adhesive. All marked clams will have a small notch filed into the ventral edge of the valves to mark the time of transplantation. Individual clams will be measured at the beginning and end of the experiment. At the end of the growing season (October 1990), clams will be removed from each of the plots described above and analyzed for growth. Wet and dry weights of clams will also be recorded so that clam condition can be compared in terms of a weight to height ratio. Hydrocarbon samples will be taken during the experiment.

To address objective A (hydrocarbons in sediments and bivalve tissues), an ANOVA will be used to test for differences in hydrocarbon content in sediment between sites. Differences in sediment hydrocarbon content will verify that control sites (areas of no oil impact) are in fact "controls". These differences will also permit post-stratification of sample sites according to level of impact. An analysis of variance will be performed on the hydrocarbon content of clam samples among sites. The results of this test will be related to the level of sediment impact.

Objective B will be met through ANOVA contingent upon the processing of necropsy samples. These samples will be processed if hydrocarbon analysis is positive.

To provide baseline (pre-impact) information on variance in growth at age among sites, an analysis of variance on growth parameters from clams taken during 1989 between areas will be conducted. Growth parameters will be determined for various growth curves, such as Gompertz, von Bertalanffy, or polynomial equations. Growth parameters will be presented for the most appropriate growth models only. A similar ANOVA will be conducted on growth parameters from clams taken during 1990 between areas. Those beach sites which are resampled in 1990 will be subjected to an analysis of variance on growth parameters obtained from fitting algorithms for clam growth after impact (1990 and beyond) and will be compared to growth parameters for clam growth prior to impact (approximately 1979-1989) to resolve impact of oil contamination on growth (Objective C). Graphics will be used to display differences in growth among areas over time, including growth curves (size at age) and growth increment at age by year for each beach.

To meet Objectives D and E, a chi-square or an appropriate nonparametric test will be used to test for significant differences in proportions of dead clams (Objective D) and young-of-the-year clams (Objective E) between treatment levels. Appropriate tests involving relative abundance measures may also be used to meet Objective E.

BIBLIOGRAPHY

Anderson, J.W., J.R. Vanderhorst, S.L. Kiesser, M.L. Fleishmann, and G.W. Fellingham. 1982. Recommended Methods for Testing the Fate and Effects of Dispersed Oil in Marine Sediments. In Oil Spill

Chemical Dispersants: Research, Experience, and Recommendations. ASTM Special Technical Publication 840. Tom E. Allen Ed. Philadelphia, PA 19103. pp. 224-238.

Anderson, J.W., R.G. Riley, S.L. Kiesser, B.L. Thomas, and G.W. Fellingham. 1983. Natural Weathering of Oil in Marine Sediments: Tissue Contamination and Growth of the Littleneck Clam, Prototheca staminea. Canadian Journal of Fisheries and Aquatic Sciences. 40(Suppl. 2):70-77.

Augenfeld, J.M., J.W. Anderson, D.L. Woodruff, and J.L. Webster. 1980. Effects of Prudhoe Bay Crude Oil-Contaminated Sediments on Protothaca staminea (Mollusca:Pelecypoda): Hydrocarbon Content, Condition Index, Free Amino Acid Level. Marine Environmental Research. 4(1980-81):135-143.

Dow, R.L. 1975. Reduced Growth and Survival of Clams Transplanted to and Oil Spill Site. Marine Pollution Bulletin. 6(8):124-125.

Dow, R.L. 1978. Size-Selective Mortalities of Clams in an Oil Spill Site. Marine Pollution Bulletin. 9(2):45-48.

Keck, R.T., R.C. Heess, J. Wehmiller, and D. Maurer. 1978. Sublethal Effects of the Water-soluble Fraction of Nigerian Crude Oil on the Juvenile Hard Clams, Mercenaria (Linne). Environmental Pollution. 15:109-119.

Neter, J., W. Wasserman, and M. Kutner. 1985. Applied Linear Statistical Models. Richard D. Irwin, Homewood Illinois.

Nickerson, R.B. 1977. A Study of the Littleneck Clam (Prototheca staminea Conrad) and the butter clam (Saxidomus giganteus Deshayes) in a habitat permitting coexistence, Prince William Sound, Alaska. Proceedings of the National Shellfisheries Association. 67:85-102.

Paul, A.J. and H.M. Feder. 1973. Growth, recruitment, and distribution of the littleneck clam, Protothaca staminea in Galena Bay, Prince William Sound, Alaska. Fishery Bulletin 71(3):665-677.

Quinn, II, T.J., and N.F. Jones. 1989. Razor Clam (Siliqua patula, Dixon) Investigations on the Eastside Cook Inlet Beaches. Juneau Center for Fisheries and Ocean Sciences, University of Alaska Fairbanks, Project Report UAF-JCFOS-8902. 165 p.

BUDGET: ADF&G

Salaries	$ 121.4
Travel	5.0
Contracts	100.8
Supplies	0.0
Equipment	2.0
Total	$ 229.2

FISH/SHELLFISH STUDY NUMBER 15

Study Title: Injury to PWS Spot Shrimp

Lead Agency: ADF&G

INTRODUCTION

This project will continue to determine possible damage to spot shrimp, <u>Pandalus platyceros</u>, due to the EVOS. Spot shrimp are a representative species of the deep water near shore benthic ecosystem, serving as a food source for a variety of fish. They are a commercially important species and also support subsistence and personal use fisheries in PWS. This project is a continuation of F/S Study 15 which was conducted during 1989-90.

Spot shrimp are known to be sensitive to oil contamination in both the larval and adult phase, and the effects of oil on spot shrimp in particular and shrimp in general are well documented (Anderson et al 1981, Brodersen et al 1977, Brodersen 1987, Mecklenburg, Rice and Karinen 1977, Sanborn and Malins 1980, Stickle et al 1987, Vanderhorst 1976). To determine the impacts that hydrocarbons from the spill may have had on spot shrimp, samples will again be collected from the three oiled and three non-oiled sites in western PWS which had been surveyed in 1989. The data collected from the samples will be analyzed to determine tissue hydrocarbon levels and tissue damage. The collected data will also be tested to confirm or reject the hypothesis that there is no significant difference in hydrocarbon levels between the oiled and non-oiled areas. Relative abundance, in terms of catch per unit effort, at each study site and changes in relative abundance over time will be tested to determine possible relationships with the level of oiling. A comparison with historical records will also be made. The size composition of the stock at each site will be estimated and, dependent upon recruitment to the fishing gear, analyzed to determine whether the 1989 year class suffered a high mortality rate in areas of high oil impact relative to other year classes in non-oiled areas. Spot shrimp fecundity will also be determined and tested for significant annual and interannual differences between oiled and non-oiled sites.

OBJECTIVES

A. Estimate the relative abundance by weight and sex of spot shrimp and the relative abundance by weight of incidentally caught pink and coonstripe shrimp in oiled and unoiled areas and compare these values to those obtained during the first assessment survey in 1989.

B. Compare size and age frequencies (by sex and depth stratum) between sites using mixture model analysis.

C. Estimate fecundity, egg mortality, and other sublethal effects between oiled and non-oiled areas over time, and determine whether those effects result in adverse changes in reproductive viability.

D. Analyze tissue and egg samples for presence of hydrocarbons and compare differences between oiled and non-oiled sites. Test the hypothesis that the level of hydrocarbons is not related to the level of oil contamination present at a site.

E. Document injury to tissues and compare differences between oiled and non-oiled sites if warranted by results from tissue hydrocarbon analysis.

METHODS

This project uses commercial spot shrimp pots of a standardized size to catch spot shrimp in oiled and unoiled areas. Shrimp specimens will be analyzed for Prudhoe Bay crude oil levels and necropsied to determine if damage has occurred to tissues as a result of oil contamination. As in the 1989 study plan, oiled and unoiled areas will be sampled in two phases which correspond with two stages of egg development. The first phase will occur in early November (1990) following the fall molt and egg extrusion. The second phase will occur in early March (1991) just prior to egg hatching. The sampling strategy will be identical during both phases. Relative abundance estimates of spot shrimp will be made using a stratified pot deployment based on depth and location. Size distribution, species composition, and reproductive data will also be collected. Previous spot shrimp research in PWS is documented by Kimker and Donaldson (1987), Donaldson (1989), Donaldson and Trowbridge (1989), and Kruse and Murphy (1989).

This project will be carried out in two general areas. One will be an area of little apparent impact, the northwestern portion of PWS. This area includes Unakwik Inlet, the site of previous ADF&G research on abundance and growth of spot shrimp. The second area will be central and southwestern PWS, an area of generally high oil impact. This area includes Green Island where ADF&G test fishing occurred in 1981. Within each of these two areas, fishing will take place at three sites. In the northwestern sound, test fishing will occur in Unakwik Inlet, Port Wells, and Culross Passage. In the central and southwestern sound, test fishing will take place near Herring Bay, Chenega Island, and Green Island. Shrimp distribution in these areas has been established by surveying the commercial fleet.

Fishing will take place at six sites - three in oiled areas and three in non-oiled areas. Each site will be stratified by depth. Stratum 1 will be shallow waters - 20 to 70 fathoms. Stratum 2 will be deep waters - 70 to 120 fathoms. Based on past research, spot shrimp are not abundant below those depth ranges. Because of the difficulty of placing the gear at precise depths, it is impractical to divide the depth into more than two strata. Strata span 50 fathoms in depth or approximately 65 to 85 fathoms in width along the bottom at slopes of 75 to 100 percent. Fishing a 100 fathom string will span the width of each strata and allow for a complete placement of gear over the strata.

Eleven pots spaced 10 fathoms apart will be fished on a long line so that each string of pots is 100 fathoms long. One 100 fathom string of gear constitutes a sampling station. Two stations will be fished in each stratum at each site for a total of 22 pots per stratum per site, or 44 pots per site. Forty-four pots is the most that can be fished in a day while collecting all of the various samples and data. If necessary, pots will be redeployed an additional day at each site and at each depth until a minimum of 500 shrimp are captured per depth stratum. A total of 264 pots will be fished during each time period.

Water temperature, salinity, and dissolved oxygen concentration by depth will be recorded using a CTD, transferred from the CTD to a micro-computer and stored on diskette. CTD casts will be at one station in the deep stratum every day. The CTD will be lowered at a rate of 60 meters per minute. Because of the configuration of the CTD, only readings from the downcast will be used.

Total weight of catch, sub-sample weight, and the weight of each species in a sub-sample will be recorded for each pot on a paper form at the time the pot is retrieved. The total weight of shrimp per pot will be determined by weighing the contents of each pot on an electronic scale. The average number of shrimp per kilogram will be determined. If less than 500 shrimp are estimated to be contained in all of the pots, all of the shrimp will be sampled. If the pots are estimated to contain more than 500 shrimp, a constant proportion by weight of each pot will be sampled for a total sample of 500 shrimp.

Each sub-sample will be sorted by species. Weight and number of animals will be recorded for each species. Only spot shrimp will be retained for further data collection. All spot shrimp in the sub-sample will be measured for carapace length to the nearest 0.1 millimeters using a digital caliper and sex will be determined as male, transitional, or female. For female spot shrimp, egg color and stage of development (eyed or uneyed); relative clutch size; presence of breeding dress and egg parasites or parasitic externa will be noted. Each female retained for fecundity analysis will be identified with a code number to allow cross reference of fecundity and other data.

Specimens for necropsy analysis will be taken after the catch is weighed and processed. Twenty shrimp from a single station in each stratum will be selected randomly to make up a necropsy sample. Necropsy samples will be labeled with the date, station number, latitude and longitude, sample number, project leader's name, species, and agency.

To prevent contamination, specimens for hydrocarbon testing will be taken from the pot immediately after removal from water and before contents are weighed. Three spot shrimp will form one composite sample. Each composite will be taken from a different pot. Two replicates of the composite will be taken randomly from one station in the stratum and the third replicate will come from the other station. Three samples per site per depth stratum result in nine samples per depth stratum (three sites X three samples) per impact level and 18 samples per oil impact level (nine samples X two depth strata). This will allow hypothesis testing to detect differences in hydrocarbon levels of 1.2 standard deviations with the probability of a type I or type II error being 0.05 and 0.10, respectively.

The number of specimens for one hydrocarbon analysis is dependent on the size of the specimens collected. Tissue volume based on the average size of the species was estimated and the number of specimens needed to provide 15 gm of tissue was calculated to be three spot shrimp. An estimate of three hydrocarbon samples from each treatment level is needed for detecting contamination between levels.

Twenty five egg bearing females will be taken at random from each station to estimate fecundity and egg mortality. A total of 24 stations will yield a total sample size of 600 females. Specimens from each station will be individually labeled. Each sample bag will be labeled with project leader's name, species name, "eggs", date, station, and agency name.

Fecundity will be determined by removing the eggs from the pleopods, drying each egg mass to a constant weight, weighing a sub-sample of a known number of eggs, and expanding the sub-sample weight to the weight of the entire clutch. Carapace length will be taken for each specimen at the time the eggs are removed and recorded on the fecundity form.

A minimum number of five shrimp from each station will be sampled for fecundity which will allow an adequate sample (30 per depth strata per oil impact level) to test for differences in fecundity between depth strata and oil impact level.

Objective A will be addressed by estimating the average catch per pot by weight, sex, and species. ANOVA will be used to test for significant differences in each of these categories between strata (depth), sites, and oiled versus non-oiled areas. To define the relationship between hydrocarbon levels and changes in relative abundance, statistics for analysis of covariance or an appropriate multivariate technique will be calculated to contrast differences in hydrocarbon content and relative abundance in oiled and non-oiled areas. Changes in average catch per pot over time will also be analyzed between different depth strata, sites, and oiled and non-oiled areas.

A size frequency distribution will be made by species and sex to address objective B. The hypothesis that there is no significant difference between strata, and oil impact levels for size frequency distribution will by tested using quantile-quantile plots, Chi-square tests or other appropriate methods. A *t* test or a similar non-parametric test will be used to test for similarity in means. Changes in size frequency distribution over time will be examined by comparing data collected during phase one and phase two. A *t* test for means and an appropriate method for comparing distributions will be used to look for significant differences between time periods as well.

To meet objective C, the relationship between size and fecundity will be examined. The percentage of spot shrimp females bearing eggs; the stage of spot shrimp egg development (color and presence or absence of eyes); the percentage of spot shrimp egg fouling and egg mortality; the fecundity by size; and the relative clutch size will be determined for each station and each phase. Chi-square tests will be used to test for differences in strata, sites and levels in data which involve percentages and proportions. Differences between strata, sites, and impact levels for fecundity and relative size of clutch will be tested for using analysis of variance. ANOVA will also be used to test for a significant difference in the above measures between phase one and phase two which may provide an estimate of the number of eggs dying over the course of the brood period or estimates of differences in egg viability.

To address objectives D and E, the average levels of oil present in spot shrimp tissue by strata and site will be estimated. Significant differences in hydrocarbon concentrations between oiled and unoiled sites will be tested by analysis of variance. To further define the impact of hydrocarbon levels on the stock, the percentage of animals with abnormal tissues in oiled and unoiled areas will be determined. A chi-square test will be utilized to test for significant differences in percentage of animals with abnormal tissues between strata, sites, and impact levels.

BIBLIOGRAPHY

Anderson, J.W., S.L. Kiesser, R.M. Bean, R.G. Riley, and B.L. Thomas. 1981. Toxicity of chemically dispersed oil to shrimp exposed to constant and decreasing concentrations in a flowing system. In: 1981 Oil Spill Conference (Prevention, Behavior, Control, Cleanup), Proceedings. Washington D.C. American Petroleum Institute. pp. 69-75.

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. In: 1977 Oil Spill Conference (Prevention, Behavior, Control, Cleanup), Proceedings. Washington, D.C. American Petroleum Institute. pp. 575-578.

Brodersen, C.C. 1987. Rapid narcosis and delayed mortality in larvae of king crabs and kelp shrimp exposed to the water-soluble fraction of crude oil. Marine Environmental Research. 22(1987):233-239.

Donaldson, W. 1989. Synopsis of the Montague Strait experimental harvest area 1985 - 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2C89-04. 21 pp.

Donaldson, W. and C. Trowbridge. 1989. Effects of rigid mesh panels on escapement of spot shrimp (Pandalus platyceros) from pot gear. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2C89-05. 22 pp.

Kimker, A. and W. Donaldson. 1987. Summary of 1986 streamer tag application and overview of the tagging project for spot shrimp in Prince William Sound. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Management Area Data Report 1987-07.

Kruse, G. and P. Murphy. 1989. Summary of statewide shrimp workshop held in Anchorage during October 24-26, 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 5J89-##.

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. In: D.A. Wolfe (ed.). Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms. Pergamon Press, New York, NY. pp. 221-228.

Sanborn, H.R. and D.C. Malins. 1980. The disposition of aromatic hydrocarbons in adult spot shrimp (Pandalus platyceros) and the formation of metabolites of naphthalene in adult and larval spot shrimp. Xenobiotica. 10(3):193-200.

Stickle, W.B., M.A. Kapper, T.C. Shirley, M.G. Carls, and S.D. Rice. 1987. Bioenergetics and tolerance of the pink shrimp (Pandalus borealis) during long-term exposure to the water-soluble fraction and oiled sediment from Cook Inlet crude oil. In: W.B. Vernberg, A. Calabrese, F.P. Thurberg, and F.J. Vernberg (eds.). Pollution Physiology of Estuarine Organisms. Belle W. Baruch Libr. Mar. Sci. 17, Univ. S. C. Press, Columbia. pp. 87-106.

Vanderhorst, J.R., C.I. Gibson, and L.J. Moore. 1976. Toxicity of No. 2 fuel oil to coonstripe shrimp. Marine Pollution Bulletin. 7(6):106-108.

BUDGET: ADF&G

Personal Services	$ 44.0
Travel	1.4
Contractual	15.0
Supplies	4.6
Equipment	0.0
Total	$ 65.0

FISH/SHELLFISH STUDY NUMBER 17

Study Title: Injury to Demersal Rockfish and Shallow Reef Habitats in PWS and Along the Lower KP

Lead Agency: ADF&G

INTRODUCTION

In light of the findings of the first year of study of potential impacts on rockfish populations conducted in 1989, continued study of demersal rockfish populations and shallow reef habitats is warranted for 1990. Unlike many species of marine fish, demersal rockfish complexes are relatively sedentary, residing near rocky reefs and boulder fields. The potential impact of the oil spill on various nearshore assemblages is dependent upon location of various rockpiles. The potential uptake of various contaminants will be related to the level of oil contamination and food web characteristics of these reefs. Of primary importance are questions of transport of oil to subsurface habitats and the potential for residual persistence of this contamination. Khan (1987) reports that crude oil can contaminate sediments and persist for long periods of time in the environment.

Under these conditions, the petroleum hydrocarbons can exert a broad range of effects on animals, from impaired feeding, growth, reproduction, and changes in behavior; to tissue and organ damage, damage to blood cells, changes in enzyme activity and changes in parasite densities (Khan 1986; Khan 1987; Kiceniuk and Khan 1986; Rice 1985; Wennekens et al. 1975; Malins et al. 1977; Rice et al. 1977; Gundlach et al. 1983; Hose et al. 1987; Spies et al. 1982). These possible affects are especially critical to demersal rockfish since they are long-lived, recruitment is low, and the potential for long-term stock decline due to chronic exposure to crude oil is high. Continuation of this study will help determine long term histopathological effects on the fish and will quantify the extent to which hydrocarbons persist in the environment.

Only limited baseline data are available for rockfish populations in PWS and along the lower Kenai Peninsula (LKP). Rockfish were studied as part of a study of nearshore fish assemblages during the years 1977-1979 in PWS (Rosenthal, 1980) and Morrison studied select reefs along the LKP during 1980 through 1984. These investigations provided descriptions of selected rockfish populations including estimates of species and prey composition, density, length and age composition.

OBJECTIVES

A. Determine the presence or absence of hydrocarbons in demersal rockfish, benthic prey species, benthic suspension feeders, and sediments from two control and two treatment sites in PWS and two control and two treatment sites along the LKP.

B. Determine the physiological effects resulting from oil contamination through histopathological examination of five organs, enzyme activity, examination of red blood cells for circulating micronuclei; and the examination of developing embryos.

C. Determine the feasibility of using toxicological analysis of gonads and pituitary glands to ascertain effects of oil contamination on growth and reproduction.

D. Determine the feasibility of using otolith microstructure to evaluate depressed growth as a result of oil contamination.

METHODS

Eight sites (four treatment and four control) in PWS and along the LKP will be sampled in 1990. Demersal species of rockfish, benthic and epibenthic invertebrates, and finfish prey species, unconsolidated benthic sediments and sessile suspension feeders will be collected at each sample location for analysis of hydrocarbons. From the results of these analyses the mechanism of hydrocarbon uptake in demersal rockfish and the extent to which hydrocarbons persist in reef ecosystems may be determined. The effects of sublethal hydrocarbon contamination in demersal rockfish may be determined through histopathological examination of five organs; evaluation of enzyme activity; examination of red blood cells for circulating micronuclei; and, the examination of developing embryos. The feasibility of evaluating affects on growth and fecundity through toxicological and biochemical analysis of gonad and pituitary tissues, as well as determining depressed growth through examinations of otolith microstructures, will be explored. Results will be compared between control and treatment sites. A pilot sampling trip will be made to determine what species are present and to evaluate sampling techniques and site selection.

Criteria for choosing sample reefs were based on: (1) accessibility to boat and diving operations (ocean floor surrounding the reefs were approximately 20 fathoms or less in depth); (2) exposure of surface waters to oil; (3) location of reported kills and/or sublethal contamination of demersal rockfish; (4) occurrence of sampling by other oil spill assessment studies relative to this study and (5) previous study sites of Rosenthal or Morrison.

A systematic sampling design will be used to identify sampling sites within each reef. Transects will be established at discrete depths by deploying an anchor line along specific contours of the reef and each end will be marked by anchored flag pole assemblies. Coordinates, length, depth, and orientation of the transect will be recorded. The actual number of sample sites will be depend on the length of the transect and the orientation of the reef in the ocean currents. During the pilot sampling trip prey and benthic species that are common to all reefs and that are not transient will be listed as target species. These species will then be collected at each reef during the sampling trip. Sampling will be conducted during late July and early August, the time frame that Rosenthal (1980) identified as near the peak abundance of rockfish in nearshore areas. Collection methods for finfish, prey species, sediment, and sessile invertebrates are outlined below.

Twenty adult demersal rockfish (target primarily yelloweye rockfish Sebastes ruberrimus) will be collected at each sample site using hook and line jigging techniques. The sample size is based on the number required for histological evaluation as determined by the Histopathology Technical Group (Meyers, 1989). Baited lures will be lowered to the substrate and raised enough to allow for adequate jigging action. When a fish is on the line it will be retrieved slowly in order to allow the air bladder to equilibrate and prevent extrusion of the stomach and regurgitation of its contents. Where excessive depths make this impractical, divers will enclose the fish in a dive net to retain the stomach contents upon regurgitation. Where hook and line techniques do not yield results divers will verify the presence or absence of demersal rockfish assemblages and if, present, collect them using spear guns. Stomach contents will be collected to determine composition of the prey species. Species identification of adult rockfish will be accomplished using the methods of Kramer and O'Connell (1988) and Hart (1973).

Fifty juvenile demersal rockfish will be collected using variable mesh, monofilament gillnets set in the shallow areas of the reef and in intertidal zones adjacent to the reefs. Given estimated proportions of 0.6 and 0.2 respectively, sample size was determined (Zar 1984) to be 50, where a =.05. Species identification of juvenile rockfish species will be accomplished using the methods of Matarese et al. (1989).

Ten samples of prey species (Rice, 1990) at each reef will be collected for hydrocarbon analysis. The sample size is based on the number required for hydrocarbon analysis as established by the Analytical Chemistry Group (Manen, 1989). The species to be collected will be determined during the pilot sampling trip. Additional information used to select prey species will be based on the analysis of stomach content samples and previous food ecology studies (Rosenthal et al., 1988; Rosenthal, 1980). Divers outfitted with SCUBA gear will use an air-lift sampler to collect benthic prey species at each site (Chess, 1978). The air-lift sampler uses suction to collect all organisms from a square meter area and deposits them into a sampling container. Additional food organisms may be collected using a variety of other techniques depending on the target species. Crab pots and shrimp pots will be used to collect crustacean species. Trammel nets, plankton tows, and diver controlled nets will be used to capture appropriate target species.

Nine sediment samples (Rice, 1990) will be collected at each sample site by divers outfitted with SCUBA equipment prior to the collection of air-lift samples outlined above. Each sample will consist of ten 2 cc scoops taken from the top 2 cm of the substrate along a 10 m long transect. Excess water will be poured off at the surface and the sample will be frozen. Three sediment samples will be collected at each reef.

Three samples of sessile filter feeders (Rice, 1990) will be collected from each reef by divers outfitted with SCUBA equipment. Each sample will consist of pieces of two or three sessile filter feeders. Enough samples will be collected to at least half fill a 4 oz. hydrocarbon sampling jar.

Samples collected will be handled differently depending upon the data required and type of analysis being conducted. The following sections explain each type of preparation that will be used. Most samples collected will be used for only one type of analysis, however, each rockfish captured will be used or prepared for a variety of purposes. Rockfish will be processed in the following specific order: 1) immediately after capture blood samples will be drawn and slides prepared; 2) rockfish will be measured to the nearest millimeter (fork length) and weighed to the nearest gram for calculation of condition factor; 3) tissue will be sampled for hydrocarbon analysis and histopathological evaluation according procedures outlined in proceeding sections; and, 4) otoliths will be removed for later age determination.

Length (fork length), to nearest millimeter, and weight, to the nearest gram, will be used to calculate a relative condition factor. Condition factors will be calculated for all rockfish captured.

Ten of the 20 rockfish (Rice, 1990) collected at each reef will be prepared for hydrocarbon analysis. All samples will be collected from live fish. Bile samples will be collected first by removing the whole gall bladder and emptying the bile into 0.5 oz. amber sampling jars. Ten grams each of stomach, pyloric caeca, liver, and muscle tissue will be collected from each rockfish. Each tissue type will be stored in separate 4 oz. sampling jars.

Ten samples of prey species (Rice, 1990) will be collected at each reef. Different preparation methods will be conducted depending upon the prey species being collected. Larger fish will be handled in the same manner as the rockfish. Smaller fish, and other small organisms where dissection is not practical, will be collected whole in sufficient numbers to fill a 4 oz. sampling jar half to three-quarters full.

Twenty live demersal rockfish, including the ten sampled for hydrocarbons, will be collected at each reef for histopathological analysis and processed under the guidelines outlined by the Histopathology Technical Group (Meyers, 1989). Blood samples will be collected using a heparinized syringe inserted between the vertebrae in the caudal peduncle and smears made and fixed for later staining with May-Grunwald-Giesma stain. The liver will be visually examined for discoloration, blotchiness, and firmness and its condition recorded. One centimeter sections of tissue will be removed from the following organs: liver-pancreas, kidney, gills, gonads, and eyes. All developing embryos will be collected and preserved in a neutral formalin solution.

Sagittal otolith pairs will be collected from fifty juvenile yelloweye rockfish (measuring less than 200 mm) from each reef. Age validation studies involving daily growth increments, such as Boehlert and Yoklavich (1987), typically utilize otoliths from juveniles because growth is deposited more rapidly, and physiological checks and daily growth increments are more visible. Upon collection, otoliths will be rinsed and stored dry in pairs in coin envelopes.

Juvenile otoliths will be prepared for examination following methods outlined by Boehlert and Yoklavich (1987). Otoliths will be viewed under transmitted light with a compound microscope at 400X magnification. Presence and location of hyaline zones comprising annuli, daily growth increments, and checks resulting from physiological factors including a reduction in growth will be examined. The feasibility of distinguishing differences in the type of zones will be explored by measuring the width of growth zones deposited over consecutive periods of time (days and years). Where physiological checks are clearly discernible from annuli, the presence of checks will be determined with respect to annuli. Checks deposited within the growth zone of the previous year will be noted. The proportion of otoliths containing checks within this growth zone will be compared between control and treatment groups.

DATA ANALYSIS

Data analysis will consist primarily of the comparison of results between control and treatment groups for each of the following:

LeCren's relative condition factor (K_n) (Anderson and Gutreuter, 1983) will be calculated for each adult and juvenile rockfish. The mean condition factor for adult and juvenile rockfish for each reef will be calculated and differences between control and treatment groups will be tested using ANOVA.

Rockfish tissues, prey species and sessile filter feeders will be analyzed for presence of hydrocarbons. Proportions of contaminated samples in each category will be compared between control and treatment groups.

For each species the proportion of treatment sites containing contaminated samples will be compared to the proportion of control sites with contaminated samples using a two-sampled z-test from Zar (1984).

Tissues will be examined for histopathological abnormalities and enzyme activity, and blood will be examined for circulating micronuclei by the Histopathological Technical Group. The proportion of samples showing evidence of histopathological abnormalities will be compared between control and treatment groups for each tissue type using the z-test from Zar (1984).

Otoliths from juvenile demersal rockfish will be examined as described in the methods section. Proportion of otoliths containing checks between the last two annuli will be compared between control and treatment groups using the z-test from Zar (1984). Age composition and mean length-at-age will be calculated for each species of rockfish.

BIBLIOGRAPHY

Anderson, R.O., and S.J. Gutreuter. 1983. Length, weight, and associated structural indices. Chapter 15 IN: Fisheries Techniques, L.A. Neilson and D.L. Johnson eds., American Fisheries Society, Bethesda, Maryland.

Boehlert, G.W. and M.M. Yoklavich. 1987. Daily growth increments in otoliths of juvenile black rockfish, Sebastes melanops: An evaluation of autoradiography as a new method of validation. Fishery Bulletin: Vol. 85, No. 4. pp. 826-832.

Chess, J.R. 1978, An airlift sampling device for in situ collecting of biota from rocky substrate. Marine Technology Society Journal, 12:20-23.

Gundlach, E.R., P.D. Boehm, M. Marchand, R.M. Atlas, D.M. Ward, and Douglas A. Wolfe. 1983. The fate Amoco Cadiz oil. Science 221:122-129.

Hart, J.L. 1973. Pacific Fishes of Canada. Bulletin 180, Fisheries Research Board of Canada. Ottawa, Ontario, Canada. pp. 388-453.

Hepler, K., A. Hoffmann, and T. Brookover. 1989. Injury to rockfish in Prince William Sound. State/Federal resource damage assessment data summary report. Fish/Shellfish Study

Number 17. ADF&G Sport Fish. Anchorage, Alaska.

Hose J.E., J.N Cross, S.G. Smith and D. Deihl. 1987. Elevated circulating erythrocyte micronuclei in fishes from contaminated sites in California. Marine Environmental Research, 22:167-176.

Khan R.A. 1986. Effects of chronic exposure to petroleum hydrocarbons on two species of marine fish infected with hemoprotozoan, Trypanosoma muranensis. Can. J. Zool. 65:2703-2709.

Khan R.A. 1987. Crude oil and parasites in fish. Parasitology Today, 3:99-102.

Kiceniuk J.W. and R.A. Khan. 1986. Effects of petroleum hydrocarbons on Atlantic cod, Gadus Morhua, following chronic exposure. Can. J. Zool. 65:490-494.

Kramer, D.E. and V.M. O'Connell. 1988. Guide to Northeast Pacific Rockfishes Genera Sebastes and Sebastolobus. University of Alaska Marine Advisory Bulletin No. 25.

Malins, D.C., E.H. Gruger, Jr., H.O. Hodgins, N.L. Karrick, and D.D. Weber. 1977. Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformations, as reflected by morphological, chemical, physiological, pathological, and behavioral indices. OCS Energy Assessment Program. Seattle, Washington.

Manen, C. A., Chairperson. 1989. State/federal damage assessment plan, Analytical Chemistry Group, National Marine Fisheries Service, Auke Bay, Alaska.

Matarese A.C., A.W. Kendall Jr., D.M. Blood, and B.V. Vinter. 1989. Laboratory guide to early life history stages of northeast Pacific fishes. NOAA Tech. Rep. NMFS 80. National Oceanic and Atmospheric Adm., National Marine Fisheries Service. Seattle, Washington 98115. 625 pp.

Meyers, T. R., Chairperson. 1989. State/federal damage assessment plan, Histopathology Technical Group, Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement, and Development Division, Juneau, Alaska.

Rice, S.D., J.W. Short, and J.P. Karinen. 1977. Comparative oil toxicity and comparative animal sensitivity. In: "Fate and effects of petroleum hydrocarbons in marine organisms and, ecosystems, Proceedings", Wolfe, Douglas A., ed., Pergamon Press, New York. pp. 78-94.

Rice, S.D. 1985. Effects of oil on fish. Chapter 5 IN:

Petroleum effect in the Arctic environment. F.R. Engelhardt ed. pages 157-182. Elsevier Applied Science Publishers, London.

Rice, S.D. 1990. Personal communication. Analytical Chemistry Group, National Marine Fisheries Service, Auke Bay, Alaska.

Rosenthal, R.J., Victoria Moran-O'Connell and Margaret C. Murphy. 1988. Feeding ecology of ten species of rockfishes(Scorpaenidae) from the Gulf of Alaska. Calif. Fish and Game 74:16-37.

Rosenthal, R.J. 1980. Shallow water fish assemblages in northeastern gulf of Alaska: habitat evaluation, species composition,abundance, spatial distribution and trophic interaction. Prepared for NOAA, OCSEAP Program. 84 pp.

Rubin, J. 1988. A review of petroleum toxicity and fate in the marine environment, with implications for the development of a penalty table for spilled oil. Institute for Marine Studies, University of Washington. Seattle, Washington.

Spies, R.B., J.S. Felton, and L. Dillard. 1982. Hepatic mixed-function oxidases in California flatfishes are increased in contaminated environments by oil and PCB ingestion. Marine Biology 70:117-127.

Wennekens, M. P., L. B. Flagg, L. Trasky, D. C. Burbank, R. Rosenthal, and F. F. Wright. 1975. Anatomy and potential costs of an oil spill upon Kachemak Bay. Alaska Department of Fish and Game, Habitat Protection Section Anchorage, Alaska.

Zar, J.H. 1984. Biostatistical Analysis. Prentice Hall, Inc., Edgewood Cliffs, New Jersey.

BUDGET: ADF&G

Personnel	$ 40.9
Travel	2.7
Services	63.6
Supplies	1.2
Equipment	1.0
Total	$ 109.4

FISH/SHELLFISH STUDY NUMBER 18

Study Title: Prince William Sound Trawl Assessment

Lead Agency: NOAA

INTRODUCTION

This project is a continuation of a multispecies trawl survey to collect samples from bottomfish for hydrocarbon analyses. Its purpose is to determine if bottomfish in PWS are still exposed to oil or oil components from the EVOS and, if so, the geographical extent of the exposure. The study will be conducted for 12 days during June 1990.

OBJECTIVES

A. Collect bile and tissue samples, and stomach contents from bottomfish, especially the utilized species.

B. Use CTD instrument to profile water characteristics throughout the sampling area.

C. Preserve any fish observed with abnormalities of any type for subsequent analysis.

METHODS

Sample collection will be done from the RV John N. Cobb using 400-mesh Eastern otter trawls at known trawl locations in the Sound. CTD profiles will be taken at each trawl station to provide information on the structure of water masses.

Because the samples must be obtained from live fish, the hauls will be of short duration (probably 10 minutes or less) to avoid death from capture. The fish will be placed in live tanks and samples taken immediately after capture. Procedures for taking samples will be the same as in the 1989 survey, with the exceptions that the samples will be obtained only from live fish and that samples will be frozen immediately after being taken.

Six tows per day are planned for each of the 10 days. The 60 tows will be distributed among the areas and depth strata used for the 1989 summer survey. The 1989 summer survey sampled six areas but the 1990 survey will sample only five of the six areas; one area, Port Wells, had negligible catches in 1989 and this area will not be sampled in 1990. The same depth strata used for the 1989 sampling will be used for the 1990 sampling:

Stratum	Depth (fm)
1	10-50
2	51-100
3	101-200
4	201-400

Eleven depth strata occur in the five areas:

Area	Depth strata to be sampled
Hinchenbrook	2,3
Orca/Fidalgo	1,2
Central Basin	3,4
Knight Island	2,3,4
Outside	2,3

The tows (60) will duplicate the 1989 stations to maximize the number of successful tows and provide coverage throughout the Sound. The stations to be sampled in 1990 include both oiled and unoiled 1989 areas and extend from the central basin south to Montague Strait. Species that will be sampled will include halibut, walleye pollock, flathead sole, and Pacific cod. The maximum number of live individuals that can be handled will be processed prior to retrieving the next tow. Halibut and pacific cod are not anticipated to be as common in the hauls as walleye pollock and flathead sole. If time permits at the end of the cruise, stations where halibut and walleye pollock were few in number will be resampled to increase the number of hydrocarbon samples for these species.

Exposure of fish to oil will be determined by measuring concentrations of metabolites of aromatic petroleum compounds in bile. Analytical procedures used for the bile metabolite assays will likely include excitations/emission measurements at wavelengths where naphthalene and phenanthrene fluoresce. If exposure is documented through bile analysis, analysis of tissue and stomach content samples will occur. Estimated exposures to petroleum hydrocarbons will be available to other investigations (particularly Study Number 24) to assess environmental damage using statistical and simulation models. These other studies will meld bile and tissue chemistry to establish relationships between biological damage and estimated exposures to hydrocarbons

BUDGET: NOAA

Salaries	$ 65.4
Travel	10.7
Ship Coast	100.0
Supplies	10.0
Equipment	0.0
Total	$ 186.1

FISH/SHELLFISH STUDY NUMBER 22

Study Title: Injury to Crabs Outside PWS

Lead Agency: NOAA

INTRODUCTION

Dungeness crabs in Alaska occupy nearshore areas in protected bays and estuaries. These habitats are usually characterized by fine benthic sediments and minimal wave action. If oil becomes incorporated in shallow subtidal sediments it persists and can affect crab populations for several years after an oil spill (Krebs and Burns 1977, Boehm et al. 1987). Dungeness crab may be especially susceptible to contamination by petroleum hydrocarbons because they often burrow into benthic sediments; ovigerous female Dungeness crab, in particular, are known to spend long periods (up to 10 months) burrowed into sediments while brooding their eggs.

Several studies have documented deleterious effects on crabs exposed to petroleum hydrocarbons. Sublethal concentrations can result in early post-molt autotomy of limbs, behavioral disorders and reduced reproductive capacity (Karinen and Rice 1974, Krebs and Burns 1977, Karinen et al. 1985 and Malan 1988). Sex and reproductive state may determine responses of crabs to oil pollution. Krebs and Burns (1977) noted a greatly reduced proportion of females in populations of the fiddler crab, _Uca pugnax_, at oil contaminated sites in Buzzards Bay, Massachusetts. Reproductively active ghost crabs, _Ocypode quadrata_, are more sensitive to the water soluble fraction of crude oil than are crabs not in reproductive condition (Jackson et al. 1981).

This project is a continuation of work begun in 1989 and will provide quantitative data regarding adverse impacts on populations of Dungeness crab outside PWS as a result of the EVOS. The project will provide information on hydrocarbon levels in benthic sediments occupied by crabs as well as hydrocarbon levels in the tissues of crabs in contaminated and uncontaminated areas near Kodiak Island and the eastern Alaska Peninsula. It will also provide biological data on fecundity, reproductive capacity, and distribution and relative abundance of the crabs. These data will permit the assessment of short-term losses caused by contamination of harvestable crabs and long-term impacts owing to adverse effects on crab reproduction. The data will also contribute to the long-term data base for management of fisheries and assessment of future oil spills.

Products will include estimates of the amount of petroleum hydrocarbons taken up by the tissues of crabs inhabiting areas with contaminated sediments, estimates of the impact of hydrocarbons taken up by crab reproductive tissues on crab fecundity and reproductive capacity and identification of possible contamination pathways from sediments to crab reproductive tissues and developing eggs.

OBJECTIVES

A. Determine the levels of hydrocarbons, if present, in Dungeness crabs in oiled and unoiled sites along the eastern Alaska Peninsula and/or near Kodiak Island.

B. Assess reproductive condition of crabs in oiled and unoiled areas by measuring such variables as percentage of ovigerous crabs, fecundity and egg loss, condition and development.

C. Determine the incidence of limb loss and of abnormalities in newly formed crab exoskeletons in oiled and unoiled areas.

D. Compare the strength of larval settlement in oiled and unoiled areas using artificial substrates.

E. Identify potential methods and strategies for restoration of lost use, populations, or habitat where injury is identified.

METHODS

The study will be conducted at eight sites with populations of Dungeness crab near Kodiak Island and the eastern Alaska Peninsula. Five sites will be in oiled areas and three will be reference sites in unoiled areas. Final site selection will, of necessity, be made in the field and will depend on the presence of Dungeness crab populations as determined by diver observations. A list of candidate sites will be compiled prior to departure. Dungeness crab will be sampled by diving. Sex, carapace width, presence or absence of an egg clutch and external physical condition will be recorded for each crab.

A total of 30 live female crab[1] will be sampled from each site during each sampling period. Divers will swim three transects to collect female crabs. Three randomly-selected subsamples of ten female crab each will be taken from the divers' total catch. The specimen number, carapace width, fresh weight, clutch size and a

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[1] Determination of sample sizes for all variables covered by this project depends on estimates of sample size for comparable variables by Margaret C. Murphy in the Project Operational Plan on "The effects of hydrocarbons on reproduction in Dungeness crab."

description of the physical condition of each female crab in the samples will be recorded. The left fifth pleopod will be removed from each crab and fixed in 5% formalin for subsequent processing to estimate egg development, egg mortality and egg fouling. Three crab will be randomly selected from the ten crab in each sample, measured and sacrificed for ovaries and hepatopancreas. Three ovaries will equal one composite hydrocarbon sample. Three hepatopancreas will equal one composite hydrocarbon sample. One composite hydrocarbon sample of eggs will be taken by clipping a small portion of the egg clutch (4 g = 1/3 of pleopod) from the right fifth pleopod of each of the three crab. The remaining seven crab from the subsample of ten will be returned to the sea.

Artificial substrates will be used to assess the intensity of the settlement of larval Dungeness crab at oiled and unoiled sites. Ten artificial substrates will be installed at about 0.5 m above the bottom at each site. At those sites with eelgrass beds the collectors will be placed about 3 m apart along an isobath just below the lower limit of the eelgrass; at those sites lacking eelgrass beds the substrates will be placed 3 m apart along the 6 m isobath. The substrates will be put in place in mid-May and will be sampled for the megalopae of Dungeness crab in July and August. The substrates will be retrieved in August at the time of the second sampling.

Sediment samples will be collected at all sites. Divers will collect three composite sediment samples along a 30 m transect laid parallel to shore in the area where divers collected the crabs. Each composite sample will consist of eight subsamples collected randomly along the 30 m transect. All sediment samples collected by divers will be taken from the top 2 cm of the sediment column.

Physical oceanographic data will be collected at each site during each sampling period using an instrument that measures CTD. CTD will be recorded every 2 seconds as it is lowered to the bottom and raised to the surface. The CTD measuring instrument will be deployed once at each site during each sampling period.

Definitive analysis of the chemical composition of petroleum hydrocarbons in the sediments, tissues and eggs will be accomplished in the laboratory with gas chromatography/mass spectrometry as directed by the Analytical Chemistry Control Group. The types of analyses to be performed on the samples will be determined by the Analytical Chemistry Group and will include 1) characterization of oil in marine sediments and crab tissues, 2) total organic carbon on selected samples, and 3) size fraction analysis on representative sediment samples. Prescreening analyses of collected samples will occur prior to full gas chromatography/mass spectrometry analysis in areas of low likelihood of oiling. Details of the methods used in the chemical analyses are recorded under the Quality Assurance Program.

The number of specimens required for one hydrocarbon analysis depends on the amount of tissue available in a crab and the need for a composite sample. Three Dungeness crab are enough to provide 15 g of ovarian tissue. One pleopod from an average clutch would provide 15 g of crab eggs, but a sample representative of more than one crab is desirable. Therefore egg clips from the clutches of three crab will be combined to form a composite sample for hydrocarbon analysis. Three hydrocarbon samples from each site are the minimum needed to detect contamination between oiled and non-oiled sites. A sample size of 30 crab was estimated to be an adequate number to determine differences in reproductive output between impact levels.

All data will be tested for heteroscedasticity with Bartlett's test or equivalent. Data will be reported as means and 95% confidence intervals calculated according to a standard formula (Sokal and Rohlf 1981). Parametric statistics (analysis of variance and Scheffe's _a posteriori_ test) will be used to test for differences in means between oiled and non-oiled sites if underlying assumptions of the parametric procedures are met, otherwise nonparametric tests (eg. the Kruskal-Wallis test) will be employed. Variables to be tested will include hydrocarbon concentrations in Dungeness crab tissues, the reproductive parameters of Dungeness crabs, crab larval production and viability and hydrocarbon content of sediments in crab habitat.

Further multivariate statistics (eg. analysis of covariance, rank correlation coefficients, discriminate analysis) will be computed if the above summary statistics indicate relationships may exist between Dungeness crab hydrocarbon content, reproductive capacity, sediment hydrocarbon content, and physical oceanographic factors.

BIBLIOGRAPHY

Boehm, P. D., M. S. Steinhauer, D. R. Green, B. Fowler, B. Humphrey, D. L. Fiest, and W. J. Cretney. 1987. Comparative fate of chemically dispersed and beached crude oil in in subtidal sediments of the arctic nearshore. Arctic _40_, supp. 1: 133-148.

Jackson, L., T. Bidleman, and W. Vernberg. 1981. Influence of reproductive activity on toxicity of petroleum hydrocarbons to ghost crabs. Mar. Pollut. Bull. _12_: 63-65.

Karinen, J. F. and S. D. Rice. 1974. Effects of Prudhoe Bay crude oil on molting tanner crabs, _Chionoecetes bairdi_. Mar. Fish. Rev. _36_: 31-37.

Karinen, J. F., S. D. Rice, and M. M. Babcock. 1985. Reproductive success in Dungeness (Cancer magister) during long-term exposures to oil-contaminated sediments. Final Report-OCSEAP P-Unit 3008, Anchorage, Alaska, 28 pp.

Krebs, C. T. and K. A. Burns. 1977. Long-term effects of an oil spill on populations of the salt-marsh crab Uca pugnax. Science 197: 484-487.

Malan, D. E. 1988. The effects of Qatar light crude oil on the saltmarsh crab Sesarma catenata and its implications in the field: toxicity to adults and larvae. S. Afr. J. mar. Sci. 7: 37-44.

Neter, J., W. Wasserman, and M. Kutner. 1985. Applied Linear Statistical Models. Richard D. Irwin, Homewood, Illinois.

O'Clair, C. E. and J. L. Freese. 1988. Reproductive condition of Dungeness crabs, Cancer magister, at or near log transfer facilities in southeastern Alaska. Mar. Env. Res. 26: 57-81.

Sokal, R. R. and F. J. Rohlf 1981. Biometry. W. H. Freeman and Company, San Francisco. 859pp.

BUDGET: NOAA

Salaries	$ 28.0
Travel	8.0
Ship Costs	50.0
Contracts	12.0
Supplies	6.0
Equipment	6.0
Total	110.0

FISH/SHELLFISH STUDY NUMBER 24

Study Title: Assessment of Oil Spill Impacts on Fishery Resources: Measurement of hydrocarbons and their metabolites, and their effects, in important species.

Lead Agency: NOAA

INTRODUCTION

Preliminary analyses of data collected in 1989 indicates that several nearshore fish species were exposed to petroleum or petroleum derivatives in and around PWS, subsequent to the EVOS (Varanasi et al., 1990). Because petroleum and its components can cause severe damage to fishery resources, this study provides for the continued monitoring of the nearshore fisheries resources of PWS and adjacent areas. Such monitoring will include measurement of petroleum exposure and short-term effects, as was done in the summer and fall of 1989, but will also encompass an assessment of long-term biological effects, including measurements of reproductive dysfunction and histopathological lesions of liver, gill, kidney, and gonad.

Certain petroleum components [e.g. aromatic hydrocarbons (Ahs)] can cause reproductive toxicity and teratogenicity in rodents (Shum et al., 1979; Gulyas and Mattison 1979, Mattison and Nightingale, 1980). Similarly, reproductive impairment has been noted in benthic fish residing in contaminated areas of San Francisco Bay (Spies and Rice, 1988) and southern California (Cross and Hose, 1988). Moreover, English sole from areas of Puget Sound having high sediment concentrations of Ahs showed inhibited ovarian maturation (Johnson et al., 1988), and fish from these areas that did mature often failed to spawn after hormonal treatment to induce spawning (Casillas et al., 1990).

In general, reproductive impairment (including reduced plasma levels of the sex steroid hormone, estradiol) was found in English sole which showed evidence of exposure to aromatic compounds. Moreover, our laboratory studies have shown that plasma levels of estradiol are reduced in gravid female English sole exposed to chemical contaminants extracted from urban sediments (Stein et al., 1990), and, more importantly, our preliminary studies have also shown that exposure to Prudhoe Bay crude oil reduced plasma levels of estradiol in gravid female rock sole.

In view of our findings last year that several nearshore fish species in and around PWS have been exposed to crude oil components, including Ahs, the assessment of possible reproductive dysfunction in animals from impacted areas will be very important in determining biological damage to living marine resources as a result of the oil spill. Ovaries of selected species will be histologically examined to determine if ovarian maturation is being affected in animals from oil-impacted areas, and to determine fecundity and levels of plasma estradiol in these same animals. Combined with measurements of metabolites in bile and enzyme activities in liver, these studies will enable us to estimate the degree of reproductive dysfunction which may be occurring in oil-exposed fish.

Exposure of animals to crude oil can also result in changes at the tissue and cellular levels (National Academy of Sciences, 1985). Examples of such changes after exposure of fish to oil-contaminated sediments include liver hypertrophy and fatty liver in winter flounder (Payne et al., 1988) and the occurrence of hepatocellular lipid vacuolization in English sole (McCain et al., 1978). Certain Ahs (e.g., benzo[a]pyrene) are known carcinogens in rodents (Lutz, 1979), and studies with several bottomfish species show that, of the xenobiotic chemicals in sediments, Ahs are most strongly associated with high prevalences of liver lesions, including neoplasms (Malins et al., 1984; Myers et al., 1987; Black et al., 1983; Varanasi et al., 1987). Generally, histopathological lesions of the types noted above do not become manifest until at least several months after exposure. However, by the summer of 1990, fish in and around oil impacted sites will have potentially been exposed to petroleum components for more than one year, and juveniles of some species of salmon will have potentially been exposed during most of their developmental period. Accordingly, assessment of histopathological effects in selected species is strongly warranted, and is included in this proposal.

This study will continue to measure exposure to oil and oil components in the biota of PWS and other areas affected by the oil spill, by determining levels of hydrocarbon metabolites in bile and by measuring hepatic enzyme activities. A range of biological effects, especially indicators of reproductive dysfunction and histopathological effects will be measured. By employing such a broad spectrum of state-of-the art chemical, biochemical and biological methods, analytical data will be obtained to document the degree of exposure and resultant biological effects of petroleum hydrocarbons on economically and ecologically important fish species. This information for important Alaskan fish species, will be incorporated into models for use in estimating oil spill impacts on fishery resources.

OBJECTIVES

A. Sample selected nearshore fish species from 14 sites inside and outside PWS, with emphasis on sites outside PWS. Site selection is primarily based on data from last year's sampling and analyses. Representative sediment samples will also be taken from each sampling site for subsequent chemical analysis.

B. Estimate the exposure to petroleum hydrocarbons by measuring levels of hydrocarbon metabolites in bile of the above species from oiled and nonoiled habitats to detect significant differences in bile concentrations with a = 0.05 and b = 0.10. Additionally, stomach contents of fish showing high levels of hydrocarbon metabolites in bile will be analyzed for hydrocarbons, such to detect significant differences in concentrations with a = 0.05 and b = 0.10

C. Estimate the induction of hepatic aryl hydrocarbon hydroxylase (AHs) activity or increased levels of cytochrome P-450IA1 in the above species from oiled and nonoiled habitats such to detect statistical differences in levels of effects with a = 0.05 and b = 0.10.

D. Estimate the prevalence of pathological conditions in the above species from oiled and nonoiled habitats such to detect statistical differences in levels of effects with a = 0.05 and b = 0.10.

E. Estimate the levels of plasma estradiol, the degree of ovarian maturation, and fecundity in adult females of two of the above species (Dolly Varden char and yellowfin sole) from oiled and nonoiled habitats such to detect statistically significant differences with a = 0.05 and b = 0.10.

F. Estimate temporal changes in the parameters described in Objectives B&C, by comparing data obtained in 1990 to data obtained in 1989. In order to assess either recovery or increased damage of habitats from the oil spill, trends in these parameters must be statistically significant at a = 0.05 and b = 0.10.

G. Construct simulation models similar to those of Schaaf et. al. (1987) for important Alaskan fish species for use in estimating oil spill impacts on fishery resources. These models will incorporate pre-spill information from the fisheries literature on mortality and fecundity together with information on reproductive impairment, pathological conditions, and biochemical effects in fish exposed to petroleum hydrocarbons as a result of the spill.

METHODS

General Strategy and Approach

Samples of biota will be collected from approximately 14 sites during 1990, from mid-May to mid-June. Sites will generally be the same sites occupied last year, and will be located in potentially oil-impacted and unimpacted areas in PWS, in CI, and in embayments on the KP, Alaska Peninsula, and Kodiak Island. As feasible, the sample locations will be coordinated with A/W Study 2. Dolly Varden char and juvenile salmon will be sampled in intertidal areas, whereas flatfish (e.g. Pacific halibut, yellowfin sole, rock sole and flathead sole) will be sampled in subtidal areas. Salmon and halibut were selected primarily because of their economic importance, and flathead sole, yellowfin sole, rock sole, and Dolly Varden were selected because of their wide geographical distribution and year-round residency in the sampling areas. Surficial sediment samples for establishing levels of petroleum hydrocarbon residues will be collected at all sites, with analyses projected to be done under A/W Study 2.

Petroleum exposure of fish will primarily be assessed by measuring (a) concentrations of metabolites of aromatic petroleum compounds in bile, and (b) AHs activities in liver. These types of measurements are necessary because petroleum hydrocarbons in fish are rapidly metabolized to compounds that are not detectable by routine chemical analyses. AHs activity in fish is due primarily to a single cytochrome P-450, apparently cytochrome P-450IA1 (Varanasi et al., 1986, Buhler and Williams 1989). Measurement of hepatic AHs activity will provide a very sensitive indicator of contaminant exposure of sampled animals (Collier and Varanasi, 1987). Moreover, the induction of AHs activity indicates not only that contaminant exposure has occurred, but also that biological changes have occurred as a result of the exposure. In addition to measuring AHs activity, cytochrome P-450IA1 will be directly quantitated in selected liver or tissue samples by an immunochemical method recently developed at the University of Bergen (Collier et al., 1989; Goksøyr, 1990).

Other biological effects in fish will be estimated by examining selected species for pathological conditions and by assessing reproductive impairment in suitably mature female fish. Pathological conditions will include grossly visible abnormalities (e.g., fin erosion) and other lesions diagnosed by histological procedures (e.g., gill necrosis, liver cell necrosis). Reproductive capacity will be estimated by examining the developmental stages of ovaries and by measuring plasma levels of certain reproductive hormones (Johnson et al., 1988), in addition to measuring fecundity (Cross and Hose, 1988). The two primary species for assessing reproductive impairment are Dolly Varden char and yellowfin sole. It is anticipated that, during the proposed sampling period (May/June), these two species will be at an appropriate stage in their reproductive cycle for such assessments to be done. Concurrent laboratory studies will be conducted to determine the effects of known doses of oil and oil components on reproductive processes in these or related species.

Samples of sediment, and selected stomach contents of fish (from fish whose bile had evidence of oil exposure) will be analyzed (sediment under A/W Study 2) for hydrocarbons by recently developed, scientifically sound and cost-effective analytical procedures involving high-performance liquid chromatography, gas chromatography and mass spectroscopy (Krahn et al., 1988).

Environmental injury will be determined using statistical and simulation models, which will be developed as part of these proposed studies, as well as from other investigations with related fish species. The bile and tissue chemistry data will be used to establish relationships between biological damage and estimated exposures to petroleum hydrocarbons.

Sampling Methods

Sampling activities will be conducted at several sites in PWS and the GOA. Sample collection will be performed from a NOAA vessel (and its launches) at water depths of approximately 0 to 320 meters. At each site, sediment samples will be collected with a box corer, VanVeen or Smith-McIntyre grab. Sediments will be stored at - 20° C. The coordinates and depths of each station will be recorded.

Fish will be collected with a bottom trawl, long-line gear, gill nets, or beach seines. Bottom trawls will be performed with an otter trawl. Tows will be of 5 to 15 minutes duration. In order to reduce contamination of the catch by free oil, trawling will avoid areas of surface films or slicks. Individuals of selected target fish species will be sorted and examined for externally visible lesions; up to 30 fish of selected species will be measured, weighed, and necropsied; and tissue samples will be excised and preserved in fixative for histopathological examination or frozen for chemical analyses.

Laboratory Analyses

1. Bile Metabolite Assay (analyses done under Technical Services-1)

Samples of bile will be injected directly into a liquid chromatograph and a gradient elution conducted (Krahn et al., 1984, 1986a, b, c). Two fluorescence detectors are used in series. The excitation/emission wavelengths of one detector are set to 290/335 nm, where metabolites of naphthalene (NPH) fluoresce. Excitation/emission wavelengths of the other detector are set to 260/380 nm, where metabolites of phenanthrene (PHN) fluoresce. The total integrated area for each detector is then converted (normalized) to units of either NPH or PHN that would be necessary to give that integrated area.

2. Liver Aryl Hydrocarbon Hydroxylase (AHs) Activity and Cytochrome P-450IA1 Analysis

Hepatic microsomes will be prepared essentially as described by Collier et al. (1986) and microsomal protein will be measured by the method of Lowry et al. (1951), using bovine serum albumin as the standard. AHs activity will be assayed by a modification of the method of Van Cantfort et al. (1977) as described by Collier et al. (1986), using 14C-labeled benzo[a]pyrene as the primary substrate. All enzyme assays will be run under conditions in which the reaction rates are in the linear range for both time and protein. Cytochrome P-450IA1 will be measured by an ELISA utilizing rabbit antibodies to cytochrome P-450c isolated from Atlantic cod (Goksøyr,1990).

3. Histopathology

Histopathological procedures to be followed are described in the report from the Histopathology Technical Group for Oil Spill Assessment Studies in PWS, Alaska. Briefly, the procedures will involve the following: (a) tissues preserved in the field will be routinely embedded in paraffin and sectioned at five microns (Preece, 1972); and (b) paraffin sections will be routinely stained with Mayer's hematoxylin and eosin, and for further characterization of specific lesions, additional sections will be stained using standard special staining methods (Thompson, 1966; Preece, 1972; and Armed forces Institute of Pathology, 1968). All slides will be examined microscopically without knowledge of where the fish were captured. Hepatic lesions will be classified according to the previously described diagnostic criteria of Myers et al. (1987). Ovarian lesions will be classified as described in Johnson et al. (1988).

4. Reproductive Indicators

Reproductive activity will be assessed by examining the ovaries of the sampled fish histologically to determine their developmental stage, and for the presence of ovarian lesions that would be indicative of oocyte resorption (Johnson et al., 1988). Other parameters associated with reproductive activity will also be measured, including fecundity (Bagenal and Braum, 1971), plasma vitellogenin (Gamst and Try, 1980; DeVlaming et al., 1984) and estradiol (Sower and Schreck, 1982) levels, and gonadosomatic index (ovary wt/gutted body wt x 100). Relationships between ovarian maturation, fecundity, plasma estradiol, plasma vitellogenin, and petroleum hydrocarbon exposure will then be evaluated.

DATA ANALYSIS

Where possible, non-parametric statistical tests will be employed to avoid assumptions that the data are normally distributed. The principal non-parametric tests that will be used are Spearman rank correlation, which has about 0.91% of the power of product-moment correlation when the parametric assumptions are met (Zar, 1984), and the heterogeneity-G statistic. Spearman rank correlation will be used for estimating uptake and metabolism of petroleum hydrocarbons from oiled and non-oiled habitats when an independent measure of contamination (e.g., levels of Ahs in sediment) is available.

The heterogeneity-G statistic (Sokal and Rohlf, 1981) will be used to study prevalence of pathological conditions at oiled and non-oiled habitats. In addition, logistic regression (appropriate where the outcome variable is binomial) will be used to model the prevalences of pathological conditions in relation to contamination.

The Kruskal-Wallis test (a non-parametric form of ANOVA) will be used for supporting statistical analyses of variation in sediment and fish hydrocarbon levels at sites sampled. If the null hypothesis of no differences among sites is rejected at a = 0.05, a non-parametric multiple comparison test (Dunn, 1964; Hollander and Wolfe, 1973; Zar, 1984) will be used to determine differences between sites at a = 0.05. Principal components analysis and LOWESS (Chambers et al., 1983) will also be employed for this purpose; both are methods of exploratory data analysis rather than inferential statistical methods. Cohen (1977) will be used for computations of statistical power.

Products will include information on the distribution and concentrations of petroleum hydrocarbons and their metabolites in fish tissues and in sediments obtained from sites in Alaska; the hepatic activities of AHs and levels of cytochrome P-450IA1 in fish from sites in Alaska; and the distribution and prevalence of histopathological disorders and reproductive impairment among selected species from those sites. Chemistry data will be submitted in the form of data tables and distribution maps, and all data will be stored in computerized data management programs. Fish pathology data will be reported in the form of distribution maps, tables describing disease frequencies of each species examined, photographs of gross and microscopic properties of abnormalities, figures representing various types of biological data (e.g., length-weight, age-weight) and discussions of the relative importance of the types of abnormalities found. Comparisons of the characteristics of these abnormalities will be made with similar conditions previously reported in other marine areas of the world. The data management formats were designed in cooperation with the National Oceanographic Data Center.

BIBLIOGRAPHY

Armed Forces Institute of Pathology. 1968. Manual of Histologic Staining Methods. Third Edition (L.G. Luna, ed.) McGraw-Hill, New York, 258 p.

Bagenal, T.B. and E. Braum. 1971. Eggs and early life history. In: Methods for the assessment of fish production in fresh waters. International Biology Programme Handbook 3. (W.E. Ricker, Ed.) Blackwell Sci. Pub. Oxford and Edinborough, England, p. 165-198.

Black, J.J. 1983. Field and laboratory studies of environmental carcinogenesis in Niagara River Fish. J. Great Lakes Res. 9:326-334.

Buhler, D.R. and D.E. Williams. 1989. Enzymes involved in metabolism of PAH by fishes and other aquatic animals: oxidative enzymes (or Phase I enzymes). In: Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. (U. Varanasi, Ed.) CRC Press, Inc., Boca Raton, FL, p. 151-184.

Casillas, E., D. Misitano, L.J. Johnson, L.D. Rhodes, T.K. Collier, J.E. Stein, B.B. McCain, and U. Varanasi. 1990. Inducibility of spawning and reproductive success of female English sole (Parophrys vetulus) from urban and nonurban areas. Submitted to Mar. Environ. Res.

Chambers, J. M., W. S. Cleveland, B. Kleiner, and P. A. Tukey. 1983. Graphical methods for data analysis. Belmont, CA: Wadsworth International Group. 395 p.

Cohen, Jacob. 1977. Statistical power analysis for the behaviorial sciences. New York: Academic Press. 474 pp.

Collier, T.K., J.E. Stein, R.J. Wallace, and U. Varanasi. 1986. Xenobiotic metabolizing enzymes in spawning English sole (Parophrys vetulus) exposed to organic-solvent extracts of sediments from contaminated and reference areas. Comp. Biochem. and Physiol. 84C:291-298.

Collier, T.K. and U. Varanasi. 1987. Biochemical indicators of contaminant exposure in flatfish from Puget Sound, Wa. pp 1544-1549. In: Proceedings Oceans '87 IEEE, Washington, D.C.

Collier, T.K., B.-T. L. Eberhart, and A. Goksøyr. 1989. Immunochemical quantitation of cytochrome P450 IA1 in benthic fish from coastal U.S. waters. Proc. Pac. NW Assoc. Toxicol. 6:9. (Abstract).

Cross, J.N. and J. Hose. 1988. Evidence for impaired reproduction in white croaker (Genyonemus lineatus) from contaminated areas off Southern California. Mar. Environ. Res. 24:185-188.

DeVlaming, V., R. Fitzgerald, G. Delahunty, J. J. Cech, Jr., K. Selman, and M. Barkley. 1984. Dynamics of oocyte development and related changes in serum estradiol 17-ß, yolk precursor, and lipid levels in the teleostean fish, Leptocottus armatus. Comp. Biochem. Physiol. 77A:599-610.

Dunn, O. J. 1964. Multiple contrasts using rank sums. Technometrics 6: 241-252.

Gamst, O. and K. Try. 1980. Determination of serum-phosphate without deproteinization by ultraviolet spectrophotometry of the phosphomolybdic acid complex. Scand. J. Clin. Lab Invest. 40:483-486.

Goksøyr, A. 1990. An ELISA for monitoring induction of cytochrome P-450IA1 in fish liver samples. Manuscript in preparation.

Gulyas, B.J. and D.R. Mattison. 1979. Degeneration of mouse oocytes in response to polycyclic aromatic hydrocarbons. Anat. Rec. 193:863-869.

Hollander, M. and D. A. Wolfe. 1973. Nonparametric statistical methods. New York: John Wiley. 503 p.

Johnson, L.J., E. Casillas, T.K. Collier, B.B. McCain, and U. Varanasi. 1988. Contaminant effects on ovarian development in English sole (Parophrys vetulus) from Puget Sound, Washington. Can. J. Fish. Aquat Sci. 45:2133-2146.

Krahn, M.M., M.S. Myers, D.G. Burrows, and D.C. Malins. 1984. Determination of metabolites of xenobiotics in bile of fish from polluted waterways. Xenobiotica. 14:633-646.

Krahn, M.M., L.J. Kittle, Jr., and W.D. MacLeod, Jr. 1986a. Evidence for oil spilled into the Columbia River. Mar. Environ. Res. 20:291-298.

Krahn, M.M., L.D. Rhodes, M.S. Myers, L.K. Moore, W.D. MacLeod, Jr., and D.C. Malins. 1986b. Associations between metabolites of aromatic compounds in bile and occurrence of hepatic lesions in English sole (Parophrys vetulus) from Puget Sound, Washington. Arch. Environ. Contam. Toxicol. 15:61-67.

Krahn, M.M., L.K. Moore, and W.D. MacLeod, Jr. 1986c. Standard Analytical Procedures of the NOAA National Analytical Facility, 1986: Metabolites of Aromatic Compounds in Fish Bile. Technical Memorandum NMFS/F/NWC-102, 25 pp. (Available from the National Technical Information Service of the U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161).

Krahn, M.M., C.A. Wigren, R.W. Pierce, L.K. Moore, R.G. Bogar, W.D. MacLeod, Jr., S.-L. Chan, and D.W. Brown. 1988. Standard Analytical Procedures of the NOAA National Analytical Facility, 1988: New HPLC Cleanup and Revised Extraction Procedures for Organic Contaminants. Technical Memorandum NMFS/F/NWC-153, 52 pp. (Available from the National Technical Information Service of the U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161).

Lowry, O.H., N.J. Rosebrough, A.L. Farr, and R.J. Randall. 1951. Protein measurement with the Folin phenol reagent, J. Biol. Chem. 193:265-275.

Lutz, W.K. 1979. In vivo covalent binding of organic chemicals to DNA as a quantitative indicator in the process of chemical carcinogenesis. Mutat. Res. 65:289-356.

MacLeod, W.D., Jr., D.W. Brown, A.J. Friedman, D.G. Burrows, O. Maynes, R.W. Pearce, C.A. Wigren, and R.G. Bogar. 1985. Standard Analytical Procedures of the NOAA National Analytical Facility, 1985-1986: Extractable Toxic Organic Compounds, 2nd Ed. NOAA Technical Memorandum NMFS F/NWC-92, 121 pp. (Available from the National Technical Information Service of the U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161; PB86-147873).

Malins, D.C., B.B. McCain, D.W. Brown, S-L. Chan, M.S. Myers, J.T. Landahl, P.G. Prohaska, A.J. Friedman, L.D. Rhodes, D.G. Burrows, W.D. Gronlund, and H.O. Hodgins. 1984. Chemical pollutants in sediments and diseases in bottom-dwelling fish in Puget Sound, Washington. Environ. Sci. Technol. 18:705-713.

Mattison, D.R. and M.S. Nightingale. 1980. The biochemical and genetic characteristics of murine ovarian aryl hydrocarbon (benzo[a]pyrene) hydroxylase activity and its relationship to primordal oocyte destruction by polycyclic aromatic hydrocarbons.Toxicol. appl. Pharmacol. 56:399-408.

McCain, B.B., H.O. Hodgins, W.D. Gronlund, J.W. Hawkes, D.W. Brown, M.S. Myers, and J.H. Vandermeulen. 1978. Bioavailability of crude oil from experimentally oiled sediments to English sole (Parophrys vetulus) and pathological consequences. J. Fish. Res. Board Can. 35:657-664.

Myers, M.S., L.D. Rhodes, and B.B. McCain. 1987. Pathologic anatomy and patterns of occurrence of hepatic neoplasms, putative preneoplastic lesions and other idiopathic hepatic conditions in English sole (Parophrys vetulus) from Puget Sound, Washington, U.S.A. J. Natl. Cancer Inst. 78:333-363.

National Academy of Sciences. 1985. Oil in the Sea; Inputs, fates and effects. National Academic Press, Washington, D. C. 601pp.

Preece, A. 1972. A Manual for Histologic Technicians. 3rd edition. Little, Brown and Co., Boston, 428 pp.

Schaaf, W.E., D.S. Peters, D.S. Vaughan, L. Coston-Clements, and C.W. Krouse. 1987. Fish population responses to chronic and acute pollution: the influence of life history strategies. Estuaries 10: 267-275.

Shum, S., N.M. Jensen, and D.W. Nebert. 1979. The murine Ah locus: in utero toxicity and teratogenesis associated with genetic differences in benzo[a]pyrene metabolism. Teratology 20:365-376.

Sokal, R. and F. Rohlf. 1981. Biometry. (Second Ed.) W.H. Freeman and Co.: San Francisco, CA, 859 pp.

Sower, S. A. and C. B. Schreck. 1982. Steroid and thyroid hormones during sexual maturation of coho salmon (Oncorhynchus kisutch) in seawater or freshwater. Gen. Comp Endocrine. 47:42-53.

Spies, R.B. and D.W. Rice, Jr. 1988. Effects of organic contaminants on reproduction of the starry flounder Platichthys stellatus in San Francisco Bay. II. Reproductive success of fish captured in San Francisco Bay and spawned in the laboratory. Mar. Biol. 98:191-200.

Stein, J.E., T. Hom, H.R. Sanborn, and U. Varanasi. 1990. Effects of exposure to a contaminated-sediment extract on the metabolism and disposition of 17ß-estradiol in English sole (Parophrys vetulus). Manuscript in preparation.

Van Cantfort, J., J De Graeve, and J.E. Gielen. 1977. Radioactive assay for aryl hydrocarbon hydroxylase. Improved method and biological importance. Biochem. Biophys. Res. Commun. 79:505-511.

Varanasi, T.K. Collier, D.E. Williams, and D.R. Buhler. 1986. Hepatic cytochrome P-450 isozymes and aryl hydrocarbon hydroxylase in English sole (Parophrys vetulus). Biochem. Pharmacol. 35:2967-2971.

Varanasi, U., D.W. Brown, S-L. Chan, J.T. Landahl, B.B. McCain, M.S. Myers, M.H. Schiewe, J.E. Stein, and D.D. Weber. 1987. Etiology of tumors in bottom-dwelling marine fish. Final Report to the National Cancer Institute under Interagency Agreement YO1 CP 40507.

Varanasi, U., S-L. Chan, R.C. Clark, Jr., T.K. Collier, W.D. Gronlund, M.M. Krahn, J.T. Landahl, and J.E. Stein. 1990. Oil Spill Progress Report. Shellfish and Groundfish Trawl Assessment Outside Prince William Sound. 30 p.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall: Eaglewood Cliffs, NJ, 620 pp.

BUDGET: NOAA

Salaries	$230.0
Supplies	35.4
Travel	19.7
Equipment (disposable)	14.9
Vessel support	150.0
	$450.0

FISH/SHELLFISH STUDY NUMBER 27

Study Title: Sockeye Salmon Overescapement

Lead Agency: ADF&G

INTRODUCTION

Commercial fishing for sockeye salmon in 1989, was curtailed in upper CI, the outer Chignik districts, and the Kodiak areas due to presence of oil in the fishing areas from the EVOS. As a result, the number of sockeye salmon entering four important sockeye producing systems (Kenai/Skilak, Chignik/Black, Red, and Frazer Lakes) and two less important lake systems (Akalura and Afognak or Litnik lakes) greatly exceeded levels that are thought to be most productive. Sockeye salmon spawn in lake associated river systems. Adult salmon serve an extremely important role in the ecosystem, providing food for marine mammals, terrestrial mammals, and birds. Additionally, carcass decomposition serves to charge fresh water lake systems with important nutrients. Juvenile salmon which rear in lakes for one or two years serve as a food source for a variety of fish and mammals. Sockeye salmon are also an important subsistence, sport, and commercial species. The ex-vessel value of the commercial catch of sockeye from these lake systems has averaged about $42 million per year since 1979, with the 1988 catch worth $115 million. Sockeye salmon returns to the Kenai River system support some of the largest recreational fisheries in the State.

Overly large spawning escapements may result in poor returns by producing more rearing juvenile sockeye than can be supported by the nursery lake's productivity (Kyle et al. 1988). In general, when rearing fish abundance greatly exceeds the lake's carrying capacity, prey resources are altered by changes in species and size composition (Mills and Schiavone 1982, Koenings and Burkett 1987, Kyle et al. 1988) with concomitant effects on all trophic levels (Carpenter et al. 1985). Because of such changes, juvenile sockeye growth is reduced, mortality increases, larger percentages holdover for another year of rearing; and the poor quality of smolts increases marine mortality. Where escapements are two to three times normal levels, the resulting high juvenile densities crop the prey resources to the extent that more than one year is required to return to normal productivity. Rearing juveniles from subsequent brood-years suffer from both the poor quality of forage and from the increased competition for food by holdover juveniles (Townsend 1989). This is the brood-year interaction underlying cyclic variation in the year class strength of anadromous fish.

This project will examine the effects of large 1989 spawning escapements on the resulting progeny for a select subset of the above mentioned sockeye nursery lakes. Three impacted lake systems where the 1989 escapements were more than twice the desired levels (Kenai/Skilak in upper CI; Red and Akalura lakes on Kodiak Island) were selected. Upper Station Lake which is near the two impacted lakes on Kodiak did not receive a large escapement and will be examined as a control.

This study is necessary to obtain a more timely assessment of impact as adult sockeye, produced from the 1989 escapement, will not return until the 1994/1995 season. Further, total return data are not available for individual Kodiak sockeye systems due to the complex mixed-stock nature of the commercial fisheries and the inability to estimate stock-specific catches.

OBJECTIVES

A. Estimate the number, age, and size of sockeye salmon juveniles rearing in selected freshwater systems.

B. Estimate the number, age, and size of sockeye salmon smolts migrating from selected freshwater systems.

C. Determine effects of large escapements resulting from fishery closures caused by the EVOS on the rearing capacity of selected nursery lakes through:

   a. analysis of age and growth of juveniles and smolts
   b. examination of nursery area nutrient budgets and plankton populations.

METHODS

Numbers of adult sockeye salmon that entered selected spawning systems outside PWS prior to and during 1989 have been estimated at weir stations or by sonar. This information was collected during projects routinely conducted by the ADF&G as part of their resource management program. Optimal escapement levels, which on the average should produce maximum sustained yield, have been based on either past relationships between spawners and returning progeny or the extent of available spawning and rearing habitat. The baseline program will continue at each site including but not limited to estimates of adult sockeye escapement and collection of scales for age analysis.

For each of the 4 lake systems identified, the response (abundance, growth, and freshwater age) of rearing juveniles from the 1989 escapement will be studied through its likely period of freshwater residence, early summer 1990 to spring 1992.

The total number of juvenile sockeye in each lake will be estimated through hydroacoustic surveys conducted during the summer (late June) and fall (September-October) of 1990, 1991, and 1992. Age and size information as well as diet items will be obtained from samples of juvenile sockeye collected from concurrent mid-water trawl netting surveys. Survey transect designs for hydroacoustic sampling and tow-netting have been established for Kenai and Skilak lakes (Tarbox and King 1989), and will be developed for each additional lake in the study. The basic survey design will be a stratified random sample where each lake is subdivided into areas and survey transects randomly selected in each area. Such programs, funded through other studies, are already in place for Tustumena and Afognak lakes. Depending on densities of rearing juvenile sockeye, estimates of fish densities will be made for each transect either by echo integration or by echo counting. Total fish population estimates will be computed, by summing transect populations, along with 95% confidence intervals (Kyle 1989).

Freshwater growth and age of sockeye salmon rearing juveniles from all study systems will be determined from scale and otolith measurements made either by direct visual analysis of scales or on an Optical Pattern Recognition system. In cases where data are available (e.g., Kenai and Skilak Lakes), growth of progeny from the 1989 spawning escapements will be compared with growth (size) of progeny produced from spawnings within these systems during prior years.

The total number of smolt migrating from each system will be estimated with a mark-recapture study during 1990, 1991 and 1992 using inclined plane traps after Kyle (1983), and Tarbox and King (1989). Smolt will be captured in traps, sampled for age and size information, marked with Bismark Brown Y (a biological dye), and transported upstream of the traps and released for subsequent recapture (Rawson 1984). Periodic retesting will determine the capture efficiency of the traps under changing river conditions during the spring. Total population estimates (with 95% confidence intervals) will be made using catch efficiencies, and weekly number weighted smolt size and age information will be calculated using a computer spreadsheet developed by Rawson (personnel communication, 1985). Size and ages of sockeye smolts from the 1989 spawning escapements will be compared with smolt information from spawnings within these systems during prior years. Finally, smolt programs consistent to those for the study lakes are planned, under separate funding, for Tustumena and Afognak Lakes.

Limnological studies will monitor the response of the lakes to the high juvenile rearing densities and to estimate the carrying capacity parameters of euphotic volume, nutrient budgets (carcass enrichment), and zooplankton biomass, body-sizes, and population shifts. Approximately six limnology surveys will be conducted at two stations, during 1990, 1991, and 1992, to determine zooplankton species abundance and body-sizes, nutrient chemistry, and phytoplankton abundance for Kenai/Skilak, Red, Akalura, and Upper Station lakes. Carrying capacity parameters exist for Afognak and Tustumena lakes based on ongoing studies by FRED and Commercial Fish Divisions.

In cases where seasonal data are available (e.g., Akalura, Kenai, and Skilak lakes), limnological parameters taken during residence of the juveniles from the 1989 spawning escapements will be compared to parameters within these systems during prior years. In addition, randomized intervention analysis (RIA) will be used to detect changes in the systems with large escapements relative to a control or reference system (Carpenter et al. 1989).

In addition to RIA, the holistic approach proposed here involves several evaluation procedures to assess the effects of sockeye salmon overescapement.

First, fresh-water production from the 1989 escapements will be assessed in Kenai/Skilak, Red, Akalura, and Upper Station lakes. This will be accomplished through analysis of growth, freshwater survival (in particular over winter survival), and freshwater age of sockeye smolt populations. Also planktonic food sources will be assessed through estimation of abundance of zooplankton prey biomass and numbers of species. Any anomalies will be determined by analysis of freshwater growth recorded on archived scales, historical freshwater age composition, and modelled freshwater survivals; and from results of previous studies as well as the 1990 smolt characteristics from each of the study systems.

Second, future sockeye salmon production from the 1989 parent year and subsequent parent years will be estimated based on spawner/recruit relationships incorporating a brood-year interaction term. Losses of adult sockeye production from subsequent parent years may result from negative effects of progeny of the 1989 escapement on the lake's carrying capacity and/or from continued high escapements due to the inability to harvest the runs because of oil in the fishing area. The spawner/recruit relationships will be estimated from historical stock specific return data (where available), and generalized spawner/recruit data scaled to the carrying capacity parameters (i.e., euphotic volume and zooplankton biomass) of the nursery lakes where stock specific return data are not available (Geiger and Koenings 1990).

Third, experimental and empirical sockeye life history/production models (Koenings and Burkett 1987, Koenings et al 1989) will be used to compare salmon production by life-stage at escapement levels consistent with management goals to the 1989 escapements.

BIBLIOGRAPHY

Carpenter, S. R., J. F. Kitchell, and J. R. Hodgson. 1985. Cascading trophic interactions and lake productivity. BioScience 35:634-639.

Carpenter, S. R., T .M. Frost, D. Heisey, and T. K. Kratz. 1989. Randomized intervention analysis and the interpretation of whole-ecosystem experiments. Ecology 70:1142-1152.

Geiger, H. J., and J. P. Koenings. 1990. Escapement goals for sockeye salmon with informative prior probabilities based on habitat considerations. Journal of Fish Biology (in review).

Koenings, J. P., and R. D. Burkett. 1987. Population characteristics of sockeye salmon (Oncorhynchus nerka) smolts relative to temperature regimes, euphotic volume, fry density, and forage base within Alaskan Lakes. p. 216-234. In H. D. Smith, L. Margolis, and C. C. Wood [ed.] Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Koenings, J. P., J. E. Edmundson, G. B. Kyle, and J. M. Edmundson. 1987. Limnology field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, FRED Division Report Series No. 71:212 p.

Koenings, J. P., R. D. Burkett, M. Haddix, G. B. Kyle, and D. L. Barto. 1989. Experimental manipulation of lakes for sockeye salmon (Oncorhynchus nerka) rehabilitation and enhancement. Alaska Department of Fish and Game, FRED Division Report Series No. 96: 18p.

Kyle, G. B. 1983. Cresent Lake sockeye salmon smolt enumeration and sampling, 1982. Alaska Department of Fish and Game, FRED Division Report Series No. 17:24 p.

Kyle, G. B. 1989. Summary of acoustically-derived population estimates and distributions of juvenile sockeye salmon (Oncorhynchus nerka) in 17 nursery lakes of Southcentral Alaska. Alaska Department of Fish and Game, FRED Division Report Series No. (In review).

Kyle, G. B., J. P. Koenings, and B. M. Barrett. 1988. Density -dependent, trophic level responses to an introduced run of sockeye salmon (Oncorhynchus nerka) at Frazer Lake, Kodiak Island, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 45:856-867.

Mills, E. L., and A. Schiavone, Jr. 1982. Evaluation of fish communities through trophic assessment of zooplankton populations and measures of lake productivity. North American Journal of Fisheries Management 2:14-27.

Rawson, Kit. 1984. An estimate of the size of a migrating population of juvenile salmon using an index of trap efficiency obtained by dye marking. Alaska Department of Fish and Game, FRED Division Report Series No. 28:23 p.

Tarbox, K.E., and B.E. King. 1989. An estimate of juvenile fish densities in Skilak and Kenai Lakes, Alaska through the use of dual beam hydroacoustic techniques in 1989. Alaska Department of Fish and Game, Commercial Fish Division Regional Information Report No. 2S90-1.

Townsend, C.R. 1989. Population cycles in freshwater fish. Journal of Fish Biology 35(Supplement A):125-131.

BUDGET: ADF&G

Personnel Services	$168.2
Travel	4.9
Contractual	88.7
Supplies	52.7
Equipment	77.5
Total	$392.0

FISH/SHELLFISH STUDY NUMBER 28

Study Title: Salmon Oil Spill Injury Model and Run Reconstruction

Lead Agency: ADF&G

INTRODUCTION

There are at least two approaches to the determination of damage to PWS fishery resources. The first approach is the "bottom up" view. Here one begins with escapements in the oiled and unoiled areas and projects return based on the various life history parameters observed for the two adult return areas. The damages are the difference in adult production between the oiled and unoiled areas. The second approach is the "top down" view. Here one begins with the returns (district catches plus escapements) and estimates the stock specific return and return per specimen for oiled and unoiled areas based on a reconstruction of the run. Damages are defined as lost production of adults and are estimated from the differences in return per spawner applied to the parent escapements.

This study will estimate damages to PWS fishery resources based on both the "bottom up" (i.e. life history modeling) and "top down" (i.e. run reconstruction) views.

In the life history modeling approach, it is necessary to add together the factors at various life history stages over several individual river systems and salmon species. Examples of potential factors include: reduced growth of fry, increased mortality of eggs and fry, loss of spawning habitat, increased early marine mortality, and overescapement. The magnitude of the overall loss in productivity for an individual salmon stock can best be understood by considering the survival at each life history stage (egg, fry, smolt, subadult, adult) over the life span of all fish of the same age class, and over all age classes present in the population. Note that survival of future age classes must be considered if the detrimental effects of oiling are persistent. A bookkeeping program is necessary to take advantage of the data already being collected, and to integrate existing historical data into documentation of the actual and potential damages due to oiling.

In the "top down" view, it is necessary to estimate the stock specific return (i.e. catch plus escapement) so that return per spawner in oiled and unoiled areas can be estimated. Because the fisheries in PWS harvest mixed stocks of fish, it will be necessary to reconstruct the stock specific abundance over time in each of the fishing districts to estimate stock specific catches.

OBJECTIVES

Life History Modeling.

A. Develop a computational framework to account for specific effects of oiling on species, stock, and life history stages of salmon populations in PWS, Cook Inlet, Kodiak, and the Chignik areas.

B. Estimate the "status quo or no-oiling" values for all parameters implicit in the computational framework that are most consistent with the scientific literature and give the best description of the aggregate of stocks' historical population dynamics.

C. Estimate the "oiling" values for all parameters implicit in the computational framework that are most consistent with the synthesis of the individual stocks responses as identified in the NRDA studies and/or responses deduced from the available scientific literature.

D. Develop estimates of salmon injury by comparison of future simulations of salmon production under the "oiling" and "no-oiling" model parameter values.

Run Reconstruction.

A. Develop a computational framework for estimating stock specific abundance over time in the 8 fishing districts in Prince William Sound. The approach will be a two dimensional (multi-stock and multi-district) generalization of the comprehensive timing model of Schnute and Sibert (1983).

B. Analyze the historical timing data and tagging data necessary to develop simplifying assumptions to derive estimable parameters. Test the run reconstruction approach by reconstructing the 1988 pink salmon run, develop estimates of hatchery contribution, and compare those to the hatchery contributions observed in the coded-wire tag (CWT) study.

C. Reconstruct the 1990 pink salmon run to Prince William Sound and develop estimates of return per spawner for oiled and unoiled areas.

METHODS

The life history model and run reconstruction model will be developed by a select group of experts under contract to ADF&G.

The life history model will have the following properties:

1. The salmon stocks and areas included in this computer based mathematical model are those included in the portions of F/S studies 1-10 as approved by the trustees as well as any stocks that were observed to have suffered overescapement in 1989 as a result of the presence of oil.

2. The model will have sufficient temporal or life history structure to account for all of the potential oil related injuries that might affect the future production of salmon.

3. The model will have stochastic elements to account for natural variation.

4. The model will project future abundance of salmon by individual stocks and will enable the comparison of future scenarios of salmon abundance with and without oiling.

With regard to the run reconstruction model, the following relates the multi-stock and multi-district generalization of Schnute and Sibert (1990) for PWS Pink Salmon. There are eight fishing districts in Prince William Sound and eight stocks consisting of the aggregate of spawning streams within the respective fishing district.

Define the following:

$I_j(t)$ = cumulative entry to District j

$E_j(t)$ = cumulative escapement in District j

$X_{ij}(t)$ = cumulative entry to District j from District i

$P_j(t)$ = total number of fish in District j

$C_j(t)$ = cumulative catch in District j

$C_{ij}(t)$ = cumulative catch of stock i in District j

$$C_j(t) = \sum_{i=1}^{8} C_{ij} \qquad (1)$$

$$P_j(t) = I_j(t) + \sum_k X_{kj}(t) - C_j(t) - \sum_l X_{jl}(t) - E_j(t) \qquad (2)$$

The timing functions I_j, $X_{i,j}$, and P_j will be estimated by reconstructing back from the cumulative catches ($C_j(t)$) and cumulative escapements ($E_j(t)$). Several assumptions must be made in order to solve the above generalization of Schnute and Sibert's model. To do so requires extensive analysis of historical timing and tagging information. Examples of assumptions are: 1. Entry of pink salmon into Prince William Sound occurs in Districts 6, 7, 8 (i.e. Southwestern, Montague, and Southeastern, respectively). 2. Rate of exploitation is the same for all stocks within a given District.

DISCUSSION

Note that the life history and run reconstruction models will accommodate harvest in existing mixed stocks fisheries and will enable the comparison of alternative commercial fisheries harvest policies. This will facilitate the evaluation of fisheries restoration strategies that attempt to rebuild damaged stocks by reducing catch in fisheries that exploit stocks damaged and stocks not damaged by the oil spill.

Activities during the first year include: analyses of historical data, developing efficient software for computer simulation, and synthesis of model parameters for the no-oiling scenario. Activities during the second year include analysis of NRDA results, including run reconstruction, to developing the best estimate of the various salmon stocks response to oiling; synthesis of these results into altered parameters in the model; develop the best scientific estimates of future salmon stocks production under the no-oiling and oiling scenarios.

BIBLIOGRAPHY

Schnute, J and J. Sibert. 1983. The salmon terminal fishery: a practical, comprehensive timing model. Can. J. Fish. Aquat. Sci. 40:835-853.

BUDGET: ADF&G

Personnel	$58.9
Travel	5.2
Contractual	100.0
Supplies	1.0
Equipment	10.0
Total	$175.1

FISH/SHELLFISH STUDY NUMBER 30

Study Title: Data Base Management

Lead Agency: ADF&G

INTRODUCTION

Large quantities of data are being analyzed in order to demonstrate the fact and extent of injury to natural resources due to oiling. The purpose of this study is to make original data readily available to agency and non-agency personnel so that data analysis can be conducted, and so that all analyses can be accomplished in an efficient and cost effective manner. The data to be placed under the database management system (DBMS) will be drawn from two categories; 1) historical data necessary to the interpretation and implementation of the results of NRDA studies, and 2) data resulting from NRDA studies.

OBJECTIVES

A. To construct a cost effective DBMS to readily retrieve and order data from original data in electronic form according to user specified criteria of time, space, and selection of variables. The DBMS should be constructed to meet the following criteria, in order of priority: 1) completeness of contents, 2) speed of retrieval, and 3) ease of use in assembling primary data into data sets for further analysis by other software. Furthermore, the DBMS will take advantage of existing DBMS applications currently available in the ADF&G.

B. To develop the structural facilities for individuals to access data that is physically located at different sites. To accomplish this, a LAN (local area network) facility must be developed in the Cordova and Anchorage ADF&G offices, as well as to develop a system for linking these with existing LAN's in Juneau and Kodiak. Note that objective B, although a necessity for this project, will be met by a concurrent and separately funded project "statewide data base system" currently being implemented by ADF&G.

METHODS

A distributional data base management system, using SQL software, will be developed. The system will be flexible to accommodate the data physically located in Kodiak, Anchorage, Cordova, and Juneau.

The DBMS system will be accessed through a linked system of LAN's, (Juneau, Anchorage, Kodiak, and Cordova). The DBMS can be accessed by any user with an IBM compatible PC that has access to the Anchorage LAN. Interface software using "WINDOWS" will be developed and made available to individuals to facilitate non-programmer access to the DBMS systems.

The following data, for all species and from Prince William Sound, Cook Inlet, Kodiak, and Chignik areas, will be incorporated into the DBMS:

1. All NRDA project data.
2. Salmon escapement data, including weir counts, stream counts, aerial survey counts, and sonar counts.
3. Biological data including age composition, size, sex, growth, and stock composition.
4. Pre-emergent and egg density.
5. Groundfish and shellfish survey data.

In addition, the DBMS will have access to statewide fish ticket system data which includes commercial fisheries catch and effort data by area, species, and gear type.

This project will be developed concurrently with the development of the ADF&G statewide data base system which is being funded with State of Alaska general funds. It is the intent to develop LANS in the Anchorage and Cordova ADF&G offices. These new LAN's will be linked with existing Kodiak and Juneau LAN's to facilitate statewide access to the above DBMS as well as to accommodate the need to access data, currently in electronic form, located in Kodiak and Juneau. For example the catch data cited above is currently in the statewide fish ticket system data base which resides in Juneau. The network will accommodate all Commercial Fisheries Division personnel and have the potential capacity to be expanded to all departmental personnel.

BUDGET: ADF&G

Personnel Services	$ 80.0
Travel	5.0
Contractual	0.0
Supplies	1.0
Equipment	34.0
Total	$120.0

MARINE MAMMAL ASSESSMENT

Although the most visible impact of the EVOS on marine mammals was the large number of dead sea otters, other marine mammal species were potentially injured by the spill, including Steller sea lions, harbor seals, killer whales, and endangered humpback whales.

In 1989, seven studies were assembled and implemented to gather information on injury to marine mammals. Aerial surveys for stranded cetaceans were also conducted. Additional data on injuries to sea otters were gathered at the sea otter rehabilitation centers.

All of these studies, except one, will be continued in 1990. Marine Mammals Study Number 3, Cetacean Necropsies to Determine Injury from the EVOS, is discontinued. No oil spill related cetacean strandings are expected in the second year. Cancellation of this study does not exclude the possibility of collecting samples opportunistically, should fresh carcasses be encountered.

In many cases, the 1990 studies have been expanded and modified in response to knowledge gained during the first year and comments from reviewers and the public. The sea otter study is far more extensive than last year and will look at possible physiological and toxicological impacts that could result in long-term, sublethal injuries. The assessment of population effects is also greatly expanded and will look closely at pre and post spill populations, population dynamics, and reproductive biology. Data from studies on Steller sea lions and harbor seals will provide information on toxicological effects of the EVOS. The ongoing cetacean studies are intended to provide information on changes in cetacean use of the spill zone, to assess impacts that may not become apparent until the second year, and to corroborate information on injury to killer whales gathered during the 1989 studies.

MARINE MAMMAL STUDY NUMBER 1

Study Title: Effects of the EVOS on the Distribution and Abundance of Humpback Whales in PWS, Southeast Alaska, and the Kodiak Archipelago

Lead Agency: NOAA

INTRODUCTION

During the first year of the humpback whale damage assessment, photographs of individual humpback whales occurring in PWS and Southeast Alaska were collected from May to September 1989 to assist in determining the impact of the EVOS on humpback whale life history and ecology. In PWS, four dedicated research vessels traversed 9,623 nautical miles to search for and photograph whales, reflecting 260 days of field research. In Southeast Alaska, researchers working from five different vessels spent 1,011 hours searching for whales for a total of 230 days of field research. An additional 155 hours were spent off Kodiak conducting marine mammal sighting surveys.

Concerns about the North Pacific humpback whale stock encountering or being exposed to oil is well founded based on evidence in the literature. The humpback whale is currently listed as an endangered species. Changes in abundance of humpback whales (after being exposed for one season to the EVOS) would more likely occur in the second year.

This study will obtain photographs of individual humpback whales occurring in PWS from early June to late September 1990. Calves of the year will be documented. Photographs collected will be compared to the Alaskan photographic database for the years 1977 to 1989 to determine if changes have occurred in whale abundance, seasonal distribution, continuity of habitat usage, and mortality and natality rates. Results of this research will allow determination of the extent of injury (displacement) or loss (reduction in numbers) to humpback whale populations as a result of the EVOS.

OBJECTIVES

A. Count and individually identify humpback whales entering PWS.

B. Test the hypothesis that humpback whale distribution and abundance within PWS is similar to that reported for 1989 and previous years.

C. Test the hypothesis that humpback whale natality has not changed since the EVOS.

D. Test the hypothesis that humpback whale mortality rates have not changed since the EVOS.

METHODS

Shore-based camps (shared with personnel from the killer whale project) will be established in PWS to conduct photo-identification studies on humpback whales from small boats (June through September 1990). Camp locations will be similar to those set up in 1989. Early in the season, camps will be located in the northwestern area of PWS (Naked Island); the southwestern region at Squire Island (off the southwest side of Knight Island); and either on Hinchinbrook Island or off the northern side of Montague Island. Camps may be moved during the field season based on whale distributional data collected during the study. Each humpback whale camp will be staffed by at least two biologists equipped with one small boat. For consistency in data collection, key personnel will remain in the field throughout the 4-month period.

Weather permitting, field personnel will spend an average of 8 to 10 hours per day conducting boat surveys searching for whales. Effort will be comparable to the 1989 season. Specific areas, known for whale concentrations, will be investigated first. However, if reports of whales are received from other sources (e.g, sighting network described below) these areas are examined. If whales are not located in "known" areas and opportunistic sighting reports are not available; a general search pattern will be developed and implemented. Travel routes taken by whales will be surveyed. When whales are sighted, researchers end their general search effort and approach the whales to collect photo-identification information. A humpback whale survey form is completed for each encounter.

To obtain a high-quality photograph, an approach within 30-60 meters is required. Photographs are taken of the ventral surface of the fluke and left side of the dorsal fin.

Daily effort logs are maintained each day which will permit 1) quantification of the amount of time searching for whales versus photographing whales, 2) quantification of search effort under different weather conditions; 3) daily vessel trackline, and 4) an estimation of the number of vessels/aircraft encountered in the study area.

To increase the sighting effort within PWS to ensure that all whales are being seen and photographed, a marine mammal sighting network will be organized throughout the PWS area. This network will record all sightings of whales collected opportunistically from Alaskan State Ferries and private aircraft and boaters. Whale sightings are reported directly to the whale research vessels. Field teams respond by searching out the area where whales were reported to collect photographic data.

All photographs of humpback whales will be analyzed for individual identification. An individual whale's ventral aspect of the fluke is recorded (notes and sketches). Photographs are then grouped by individual. Each individual whale identified is then visually compared to the historical photographic database. A second, independent matching analysis will be performed to ensure accuracy. Considerable expertise exists in recognizing individual whales through computer matching of color patterns. Once all photographs are properly cataloged and evaluated, it is then possible to determine 1) the identification of individual whales and 2) if the individual whales have altered their distributional patterns.

To avoid biases in data interpretation, it is important that the amount of effort in searching for and photographing whales in 1990 is at least equal to (but not less than) that completed in previous years. When comparing differences in sightings per unit effort, either the Kolmogorov-Smirnov or Mann-Whitney test will be used.

Calves of the year will be noted and their mothers identified. Natality (number of calves per adult female) will be calculated for each area. Comparisons of natality among years will be made using either Chi-square tests or Z tests for comparing differences between two proportions (selection of test based on sample size). Stranded animals found during the 1990 season will be reported. Distributional comparisons will be made on a qualitative basis.

BIBLIOGRAPHY

The following humpback whale articles are pertinent to the studies being conducted in Alaska.

Baker, C. S. 1985. The Population Structure and Social Organization of Humpback Whales (Megaptera novaeangliae) in the Central and Eastern North Pacific. Ph.D. Dissertation. University of Hawaii. 306 pp.

Baker, C. S. and L. Herman. 1987. Alternative population estimates of Humpback Whales (Megaptera novaeangliae) in Hawaiian Waters. Canadian Journal of Zoology, 65: 2818-2821.

Hall, J. S. 1979. A Survey of Cetaceans of Prince William Sound and Adjacent Waters--their Numbers and Seasonal Movements. In: Environmental Assessment of the Alaskan Continental Shelf. NOAA OCSEAP Contract No. 01-6-022-15670. 72 pp.

Hall, J. D. 1981. Aspects of the Natural History of Cetaceans of Prince William Sound, Alaska. Ph.D. Dissertation. University of California - Santa Cruz. 148 pp.

Hall, J. D. 1982. Prince William Sound - Humpback Whale Population and Vessel Traffic Study. Final Contract Report No. 81-ABG-00265 to National Marine Fisheries Service, 20 pp.

Johnson, J. J. and A. A. Wolman. 1984. The Humpback Whale (Megaptera novaeangliae). Marine Fisheries Review 46(4):30-37.

Jurasz, C. M. and V. P. Jurasz. 1979. Feeding Modes of the Humpback Whale (Megaptera novaeangliae) in Southeast Alaska. Sci. Rep. Whales Res. Inst. No. 31: 69-83.

Katona, S., B. Baxter, O. Brazier, S. Kraus, J. Perkins, and H. Whitehead. 1979. Identification of Humpback Whales by Fluke Photographs. In: H. E. Winn and B. L. Olla (eds). Behavior of Marine Animals - Current Perspectives in Research, Vol. 3: Cetaceans: pp. 33-44. Plenum Press, New York.

Rice, D. W. 1978. The Humpback Whale in the North Pacific: Distribution, Exploitation, and Numbers. In: Report on a Workshop on Problems Related to Humpback Whales (Megaptera novaeangliae) in Hawaii. NTIS Report PB-280 794. pp. 29-44.

Watkins, W. A., K. E. Moore, D. Wartzok, and J. H. Johnson. 1981. Radio Tracking of Finback (Balaenoptera physalus) and Humpback (Megaptera novaeangliae) Whales in Prince William Sound, Alaska. Deep-Sea Research 78: 577-588.

Wing, B. L. and K. Krieger. 1983. Humpback Whale Prey Studies in Southeastern Alaska, Summer 1982. Report by Northwest and Alaska Fisheries Center Auke Bay Laboratory, 60 pp. National Marine Fisheries Service, NOAA, P. O. Box 155, Auke Bay, Alaska 99821.

von Ziegesar, O. 1984. A Survey of the Humpback Whales in Southwestern Prince William Sound, Alaska 1980, 1981, and 1983. A Report to the State of Alaska, Alaska Council on Science and Technology, 68 pp.

von Ziegesar, O. and C. O. Matkin. 1989. A Catalogue of Prince William Sound Humpback Whales Identified by Fluke Photographs Between the Years 1977 and 1988. 28 Pages. North Gulf Oceanic Society, P. O. Box 15244, Homer, Alaska

BUDGET: NOAA

Salaries	$ 0.0
Travel	6.0
Contracts	80.0
Supplies	2.0
Equipment	4.0
Total	$ 92.0

MARINE MAMMAL STUDY NUMBER 2

Study Title: Assessment of Injuries to Killer Whales in PWS, Kodiak Archipelago, and Southeast Alaska

Lead Agency: NOAA

INTRODUCTION

During the first year photographs of individual killer whales occurring in PWS, Southeast Alaska, and the Kodiak Archipelago were collected from May to September 1989 to assess the impact of the EVOS on killer whale life history and ecology. In PWS, four dedicated research vessels traversed 9,623 nautical miles searching and photographing whales, reflecting 260 days of field research.

This year's study will obtain photographs of individual killer whales occurring in PWS and adjacent waters from early June to late September 1990. Calves of the year will be documented. Photographs collected will be compared to the Alaskan photographic database for the years 1977 to 1989 to determine if changes have occurred in whale abundance, seasonal distribution, continuity of habitat usage, pod integrity, and mortality or natality rates. Results of this research will allow determination of the extent of injury (displacement) or loss (reduction in numbers) to killer whale populations as a result of the EVOS.

OBJECTIVES

A. Count the number and individually identify killer whales within PWS and adjacent waters.

B. Test the hypothesis that killer whale distribution within PWS and adjacent waters is similar to that reported for previous years (1984-1989).

C. Test the hypothesis that pre- and post-spill killer whale pod structure and integrity have remained constant.

D. Test the hypothesis that killer whale natality rates within PWS have not changed since the EVOS.

E. Test the hypothesis that killer whale mortality rates within PWS have not changed since the EVOS.

METHODS

Shore-based camps will be established in PWS to conduct photo-identification studies on killer whales from small boats (May through September 1990). Camp locations will be similar to those set up in 1989. Early in the season camps will be located in the northwestern area of PWS (Naked Island), the southwestern region at Squire Island (off the southwest side of Knight Island); and either on Hinchinbrook Island or off the northern side of Montague Island. Camps may be moved during the field season based on whale distributional data collected during the study. Each camp is staffed by at least two biologists and one small boat. For consistency in data collection, key personnel remain in the field throughout the 4-month period.

Weather permitting, field personnel will spend an average of 8 to 10 hours per day conducting boat surveys searching for whales. Effort will be comparable to the 1989 season. Specific areas, known for whale concentrations, are investigated first. However, if reports of whales are received from other sources (e.g, sighting network described below), those areas are examined. If whales are not located in known areas and opportunistic sighting reports are not available, a general search pattern will be developed and implemented. Travel routes typically taken by whales are surveyed. When whales are sighted, researchers stop further search efforts and approach the whales to collect photo-identification information. A killer whale survey form is completed for each encounter. When whales are encountered, researchers select a vessel course and speed to approximate the animals' course and speed to facilitate optimal photographic positioning.

To obtain a high-quality photograph, an approach within 30-60 meters is required. Photographs are taken of the left side of the whale's dorsal fin and saddle patch. Any high-performance camera system can be used to collect the data.

Daily effort logs are maintained each day which will permit 1) quantification of the amount of time searching for whales vs photographing whales, 2) quantification of search effort under different weather conditions; 3) daily vessel trackline, and 4) an estimation of number of vessels/aircraft encountered in the study area.

To increase the sighting effort within PWS to ensure that all whales are being seen and photographed, a marine mammal sighting network will be organized throughout the PWS area. This network will record all sightings of whales collected opportunistically from Alaskan State Ferries and private aircraft and boaters. Whale sightings are reported directly to the whale research vessels. Field teams respond by searching out the area where whales were reported to collect photographic data.

To account for the possible displacement of killer whales to areas outside PWS and to confirm that the missing whales are not elsewhere (e.g., particularly the absence of the 22 individuals of AN pod), photographic studies will be conducted off Kodiak Island.

A marine mammal sighting network will be organized throughout Alaska which includes sightings collected opportunistically from Alaskan State Ferries and private aircraft and boaters. To provide extended coverage throughout the GOA, marine mammal sighting information collected by NOAA ships and other research vessels that have been working areas of interest will be examined. All killer whale data will be extracted and summarized. If photographs were collected; an attempt will be made to obtain them.

All photographs of killer whales will be analyzed for individual identification. Each negative (or prints as needed) is placed under a dissection microscope for identification purposes and notes and sketches made. Photographs are then grouped by individuals. Each identified whale is then visually compared to the historical photographic database available at the Pacific Biological Station, Nanaimo, British Columbia, Canada. Once all photographs are properly entered and evaluated, it is then possible to determine 1) if all members of the pod were present, and 2) if pod structure/integrity is similar to previous years. Missing animals are noted. The stability of resident pods over time is such that if an individual is listed as missing for at least one year, that missing whale is considered dead.

To avoid biases in data interpretation, effort in searching for and photographing whales in 1990 will at least be equal to (but not be less than) that completed in previous years. For a large pod (>12 animals), the liklihood of obtaining photographs of all individuals are increased as the number of encounters are increased. Some individuals, and certain pods, are more likely to approach vessels making photographic documentation easier; while others keep a considerable distance away making for more difficult conditions. Whale behavior also plays a role when attempting to obtain photographs of individual whales. If the pod is resting (typically grouped together), it is easier to obtain photographs of all whales than when the pod is travelling (spread out through an area). Researchers with prior killer whale experience in a particular area who are capable of recognizing individuals, will also enhance the likelihood of accounting for all whales within a pod.

Calves of the year will be noted and their mothers identified. Natality (number of calves per adult female) will be calculated for each pod for each year and comparisons made between resident and transient groups using descriptive statistics. Mortality rates through 1989 will also be calculated for resident groups. Mortality for transient pods will be calculated when necessary data are available.

General location of whales will be recorded each time photographs are taken, allowing comparisons of pod distributions among years. Changes in normal distribution patterns will be reported.

BIBLIOGRAPHY

The following killer whale articles are pertinent to the studies being conducted in Alaska.

Anon. 1982. Report on the workshop on identity, structure, and vital rates of killer whale populations. Rept. Int. Whal. Commn, 32: 617-631..

Balcomb, K. C. 1978. Orca Survey 1977. Final Report of a Field Photographic Study Conducted by the Moclips Cetological Society in Collaboration with the U. S. National Marine Fisheries Service on Killer Whales (Orcinus orca) in Puget Sound. Unpub. Report to the Marine Mammal Division, National Marine Fisheries Service, Seattle, Washington, 10 pages.

Bigg, M. A. 1982. An Assessment of Killer Whale (Orcinus orca) Stocks off Vancouver Island, British Columbia. Rept. Int. Whal. Commn., 32: 655-666.

Braham, H. W. and M. E. Dahlheim. 1982. Killer Whales in Alaska Documented in the Platforms of Opportunity Program. Rept. Int. Whal. Commn. 32: 643-646.

Calambokidis, J., J. Peard, G. H. Steiger, J. C. Cubbage, and R. L. DeLong. 1984. Chemical contaminants in marine mammals from Washington State. Natl. Oceanic Atmospheric Admin., Tech. Memo, NOS OMS, 6: 1-167.

Ellis, G. 1987. Killer Whales of Prince William Sound and Southeast Alaska. A Catalogue of Individuals Photoidentified, 1976-1986. Sea World Research Institute/Hubbs Marine Research Center, Technical Report No. 87-200. April 1987.

Fowler, C. W. 1984. Density Dependence in Cetacean Populations. In "Reproduction in Whales, Dolphins, and Porpoises". Eds. W. F. Perrin, R. L. Brownell, and D. P. DeMaster. Rept. Int. Whal. Commn., Spec. Issue 6: 373-380.

Hall, J. D. 1981. Aspects of the Natural History of Cetaceans of Prince William Sound. Ph.D. Dissertation. University of California - Santa Cruz. 148 pp.

Heyning, J. E. and M. E. Dahlheim. 1988. Orcinus orca. Mammalian Species Account, No. 304, pp. 1-9, 4 figs.

Leatherwood, S., K. C. Balcomb, C. O. Matkin, and G. Ellis. 1984. Killer Whales (Orcinus orca) of Southern Alaska - Results of Field Research 1984 Preliminary Report. Hubbs Sea World Research Institute Tech. Report No. 84-175, 59 pp.

Leatherwood, S., A. Bowles, E. Krygier, J. D. Hall, and S.

Ignell. 1985. Killer Whales (Orcinus orca) in Southeast Alaska, Prince William Sound, and Shelikof Strait; A Review of Available Information. Rept. Int. Whal. Commn., SC/35/SM 7., 10 pp.

Perrin, W. F. and S. B. Reilly. 1984. Reproductive Parameters of Dolphins and Small Whales of the family Delphinidae. In "Reproduction in Whales, Dolphins, and Porpoises". Eds. W. F. Perrin, R. L. Brownell, and D. P. DeMaster. Rept. Int. Whal. Commn., Spec. Issue 6: 97-134.

von Ziegesar, O., G. Ellis, C. Matkin, and B. Goodwin. 1986. Repeated Sightings of Identifiable Killer Whales (Orcinus orca) in Prince William Sound, Alaska 1977-1983. Cetus, Vol. 6, No. 2, 5 pp.

BUDGET: NOAA

Salaries	$	45.0
Travel		10.0
Contracts		180.0
Supplies		10.0
Equipment		10.8
Total	$	255.8

MARINE MAMMAL STUDY NUMBER 4

Study Title: Assessment of Injury to Steller Sea Lions in PWS and the GOA

Lead Agency: NOAA

Cooperating Agency: ADF&G

INTRODUCTION

Steller sea lions (Eumetopias jubatus) are the largest and one of the most conspicuous pinnipeds inhabiting the GOA. The north GOA contains a major portion of the worldwide habitat of this species. Regularly used haulouts are located throughout PWS and along the Gulf coast. Major breeding rookeries occur at the entrance to PWS, along the eastern Kenai Coast, in the Barren Islands, in the northern Kodiak area, at Chirikof Island south of Kodiak, and in the Semidi Islands, south of Shelikof Strait (Calkins and Pitcher 1982; Loughlin et al. 1984; Merrick et al. 1987).

Steller sea lions were present in large numbers in PWS during the oil spill, were exposed to oil immediately after the spill, and may continue to be exposed for several more years. Initial observations indicated that sea lions did not attempt to avoid the oil. Oiled sea lions were reported at haulouts by several observers.

Steller sea lion populations have declined substantially in much of their range since at least 1970 (Braham et al. 1980; Calkins 1985; and Loughlin et al. 1984). This decline appears to be accelerating in the northern Gulf of Alaska (Loughlin et al. 1990; Calkins and Goodwin 1988; Merrick et al. 1987 Loughlin et al. 1984). The NMFS has listed this population as threatened under terms of the Endangered Species Act. Further reductions of this species in this area could result in adverse ecological impacts on the marine ecosystem.

Various studies and observations suggest that several thousand sea lions move across the northern GOA in the spring; probably most return to the large rookeries along the Kenai coast and northern Kodiak to pup and breed (Calkins and Pitcher 1982). Many of these animals use PWS during the period of March through May (Calkins and Pitcher 1982).

This study addresses the impacts of the EVOS on the Steller sea lion population in PWS and the GOA. Sea lion pups will be counted at rookeries from Chowiet Island to Seal Rocks. These counts will be compared between years for 1989 and 1990 as well as compared to historical data of a similar nature. The counts will be used to monitor relatively large changes which may occur in the population. Premature pupping will be investigated by comparing premature pupping rates at an area close to the oil spill (Cape St. Elias) to an area a substantial distance from the spill (Chirikof Island). It is assumed that, because of proximity, the sea lions at Cape St. Elias had a higher exposure rate to the oil than those at Chirikof Island. Premature pupping has been suggested as a possible toxicological consequence of exposure to hydrocarbons during gestation. This would not have been a likely effect in 1989 because the spill occurred late in the gestation period. Toxicological and histological examination of tissues from sea lions will provide information on absorption and possible damage caused by hydrocarbons including the pups born prematurely. Tissues have been taken from both animals collected specifically for that purpose and from animals found dead in oiled areas. All animals collected for tissue analysis were examined by a certified veterinary pathologist. Tissue analysis may show if injury occurred to sea lions.

OBJECTIVES

A. Test the hypothesis that premature pupping occurs at a higher rate at a hauling area nearer the oil spill.

B. Test the hypothesis that pup production is lower in the vicinity of the oil spill.

C. Estimate hydrocarbon levels in sea lion tissues to within 10% of the actual value 95% of the time.

D. Test the hypothesis that tissue damage has occurred.

METHODS

Premature pupping has occurred historically in the GOA sea lion population (Calkins and Goodwin 1988) and may be accelerated by toxic effects of oil. Observations and searches for aborted fetuses will be made at all hauling areas and rookeries visited after March 1989. Premature pupping will be measured at Cape St. Elias and at Chirikof Island by stationing observers at these locations for a 4 week period during April and May. Each premature birth will be recorded and each fetus will be examined. Tissues will be preserved from each animal examined for hydrocarbon and histological analysis. Adults will be counted daily at each location and a rate of premature births to adults present will be determined. Daily observations will be conducted using spotting scopes and binoculars.

Pup production will be measured by counting pups directly at the six rookeries within the oil spill area from Chowiet Island to Seal Rocks (Calkins and Pitcher 1982). Sea lions from all of these rookeries could be assumed to be impacted. This count has been conducted in June/July 1989 and will be conducted again in 1990.

In order to insure accurate hydrocarbon analysis of tissues, it is important to preserve tissues within six hours after death. Accordingly, sea lions will be collected under terms of a permit issued by the NMFS, upon consultation with NMFS, if available tissue analyses indicate further collections are warranted.

In accordance with established criteria of the histopathology technical group, a Board certified veterinary pathologist will perform histopathological analysis of all sea lion tissues and a second board certified pathologist will perform an independent, blind reading of a subsample of histology slides. Reference histology slides will be retained and archived toxicological samples will be frozen and stored.

Data analysis for comparing premature pupping between two areas to determine if the proportion of premature pups born to adults in an area close to the oil spill is higher than an area further away from the oil spill will be tested with a two sample t-statistic on rate (Snedcor and Cochran 1980) at alpha=0.05 in the lower tail. The normality assumption will be examined with Q-Q plots (Hoaglin, Mosteller and Tukey 1985) and if necessary, the data will either be transformed to meet this assumption or a Mann-Whitney, nonparametric statistic will be used (Conover 1980).

Analysis of pup counts will utilize a regression model to predict expected numbers of sea lion pups in the absence of the EVOS. Because sea lion pup numbers have been declining since 1979, the 1990 pup count will be compared to the 1989 count and historical data to determine if it is lower than what the regression model suggests. A Hotelling's T^2 statistic will be used to test if the observed 1990 count is significantly lower than the predicted value from the regression equation modeling of the pre-1989 sea lion decline (Neter and Wasserman 1974). The validity of the model will be tested using data from counts from unoiled areas.

It is assumed that the distribution of pup counts is normal. The regression model would accurately predict pup numbers in the Gulf of Alaska in the absence of the oil spill. The regression model is correctly specified, and has constant variance. The proportion of sea lions exhibiting hydrocarbon uptake will be estimated and an exact 95% confidence interval determined using the binomial distribution (Ostle and Mensing 1982).

BIBLIOGRAPHY

Braham, H. W., R. D. Everitt, and D. H. Rugh. 1980. Northern sea lion population decline in the eastern Aleutian Islands. Fish. Bull. 44:25-33.

Calkins, D. G. 1985. Sea lion pup counts in and adjacent to Shelikof Strait. Final report submitted to North Pacific Fisheries Management Council, contract 84-1. Alaska

Department of Fish and Game, Anchorage Alaska. 13pp.

Calkins D. G. and E. Goodwin. 1988. Investigation of the declining sea lion population of the Gulf of Alaska. National Marine Mammal Laboratory contract NA-ABH-00029. Alaska Department of Fish and Game, Anchorage, Alaska. 76pp.

Calkins, D. G. and K. W. Pitcher. 1982. Population assessment,ecology, and trophic relationships of Steller sea lions in the Gulf of Alaska. In: Environ. Assess. of the Alaskan Cont. shelf. Final Reports. 19:445-546.

Conover, W. J. 1980. Practical nonparametric statistics 2nd ed. John Wiley and Sons, New York. 493 pp.

Hoaglin, D. C., F. Moesteller, and J.W. Tukey. 1985. Exploring data tables, trends, and shapes. John Wiley and Sons, New York. 527 pp.

Johnson, R. A. and D. W. Wichern. 1988. Applied multivariate analysis. 2nd ed. Prentice Hall, Englewood Cliffs, New Jersey. 607 pp.

Loughlin, T. R., D. J. Rugh, and C. H. Fiscus. 1984. Northern sea lion distribution and abundance: 1956-80. J. Wildl. Manage. 48:729-740.

Loughlin, T. R., A. S. Perlov, and V. A. Vladimirov. 1990. Survey of northern sea lions (Eumetopias jubatus) in the Gulf of Alaska and Aleutian Islands. NOAA technical memorandum NMFS F/NWFC- 176. 26 pp.

Merrick, R. L., T. R. Loughlin, and D. G. Calkins. 1987. Decline in abundance of the northern sea lion Eumetopias jubatus in Alaska, 1956-86. Fish. Bull. 85:351-365.

Mendenhall, W., R. L. Scheaffer, and D. D. Wackerly. 1981. Mathematical statistics with applications. Second edition. Duxbury Press, Boston, Mass. 686pp.

Neter, J. and W. Wasserman. 1974. Applied linear statistical models: regression, analysis of variance, and experimental designs. Richard D Irwin, Inc. Homewood, Illinois. 842pp.

Ostle, B. and R. W. Mensing. 1982. Statistics in research, 3rd ed. The Iowa State Univ. Press. Ames, Iowa. 595 pp.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods. Seventh edition. The Iowa State Univ. Press, Ames Iowa. 507pp.

BUDGET: NOAA

Personnel	$ 107.4
Travel and per diem	6.0
Services	45.5
Commodities	6.8
Equipment	5.5
TOTAL	$171.2

MARINE MAMMAL STUDY NUMBER 5

Study Title: Assessment of Injury to Harbor Seals in PWS and Adjacent Areas

Lead Agency: NOAA

Cooperating Agency: ADF&G

INTRODUCTION

Harbor seals (Phoca vitulina richardsi) are one of the most abundant species of marine mammals in PWS and adjacent areas. They are resident throughout the year, occurring primarily in the coastal zone where they feed and haul out to rest, bear and care for their young, and molt (Hoover 1988). They are used for subsistence purposes by Native residents in the area. Unlike fur seals (Callorhinus ursinus) and sea lions (Eumetopias jubatus), harbor seals do not form distinct rookeries during the pupping and breeding season. Pups are born at the same locations as those used as haulouts at other times of year. Some of the largest haulout sites in PWS, and adjacent waters to those haulouts, were directly impacted by substantial amounts of oil during the EVOS. Oil that moved into the GOA impacted harbor seal habitat at least as far to the southwest as Tugidak Island. Harbor seals swam through oil and breathed at the air/water interface. On haulouts they crawled through and rested on oiled rocks and algae. Pups were born on the haulouts in May and June while some of the sites still had oil on them, resulting in pups becoming oiled. The same locations were also used during the molt in August and September.

Trend count surveys indicate that the number of harbor seals in PWS declined by 40% from 1984 to 1988, and similar declines have been noted in other parts of the northern GOA (Pitcher 1989). Additional impacts on harbor seal populations are therefore of particular concern.

Three ringed seals (Phoca hispida) exposed in the laboratory to fresh Norman Wells crude oil all died within 71 minutes; six seals exposed for 24 hours at a field site showed minor damage to the eyes, kidneys, and liver (Geraci and Smith 1976). Hydrocarbons were rapidly absorbed into the body fluids and tissues when ringed seals were exposed to oil by either immersion or ingestion (Engelhardt et al. 1977). In 1974, oil from an unknown source came ashore at a grey seal (Halichoerus grypus) pupping beach in Wales. Two pups drowned when they became so encased in oil that they were unable to swim, and oiled pups reached a lower peak weight at weaning than did unoiled pups (Davis and Anderson 1976).

Following the spill, field observations were made of seals in oiled and unoiled areas of PWS. Carcasses of 39 seals were necropsied and sampled; 19 that were found dead or died in captivity, and 20 that were collected specifically for sampling. Histopathological and toxicological analyses are in progress.

Last year aerial surveys were conducted during June to count the number of harbor seal pups and non-pups on 25 oiled and unoiled haulouts in PWS. Aerial surveys were also conducted at the same 25 haulouts during the fall molt. Results of the fall surveys have been compared to results of surveys flown in 1984 and 1988 to determine whether trends in numbers are similar in oiled and unoiled areas.

This project proposes to complete histopathological and toxicological analyses of harbor seal tissues and to provide counts of harbor seals on haulouts in oiled and unoiled parts of PWS and during pupping and molting in two additional years (1990 and 1991). Data from aerial surveys will be used to evaluate whether changes occurred in the distribution and abundance of harbor seals following the EVOS, and whether such changes coincided with the presence or absence of oil in the area or on the haulouts. Toxicological analyses of tissues from oiled and unoiled seals will allow an assessment of whether hydrocarbons were assimilated by the seals and how contaminant levels changed over time. Histopathological examinations will determine the types and degrees of toxic damage to tissues. Survey and laboratory data, in combination with historical data for PWS, will be used to evaluate whether the EVOS caused a reduction in pup productivity at oiled sites in 1989 and 1990, and whether changes in abundance during the 1989 fall molt were due to the EVOS. This information can then be used to make recommendations regarding restoration of lost use, populations, or habitat where injury is identified.

OBJECTIVES

A. Test the hypothesis that harbor seals found dead in the area affected by the EVOS died due to oil toxicity.

B. Test the hypothesis that seals exposed to oil from the EVOS assimilated hydrocarbons to the extent that harmful pathological conditions resulted.

C. Test the hypothesis that the abundance of harbor seals on the trend count route during pupping and molting decreased in oiled areas of PWS as compared to unoiled areas.

D. Test the hypothesis that pup production was lower in oiled than in unoiled areas, or than in years not affected by the EVOS.

METHODS

For one week during pupping in June 1990, small boats will be used to observe seals and seal haulouts in oiled areas. Haulout sites will be inspected for the presence of oil or dead animals. Seals will be examined using 7 to 10-power binoculars and a 25-power spotting scope to determine whether any have oiled pelage. Seals observed will be classified as to the degree of pelage oiling (heavy, moderate, light, or none). If any carcasses are found that are in suitable condition, they will be necropsied by trained biologists, veterinarians, or pathologists, and samples will be obtained and preserved for toxicological and histopathological examination.

A maximum of 12 additional harbor seals will be collected, under a permit from NMFS. Most will be collected at or adjacent to sites impacted by the EVOS. One or more seals will be collected from an area not impacted by the spill, such as southeast Alaska. Each animal will be necropsied as soon as possible after death by qualified personnel.

Collected animals will be measured, weighed, and photographed; time, date, location, and circumstances of collection will be noted; and any gross abnormalities will be recorded. Blood samples for serum, plasma, and whole blood analyses will be taken. Samples will be taken for histopathology and toxicology. Chain of custody will be maintained for all samples. Samples for histopathology will be stored in formalin until they are analyzed. Reference histology slides will be retained and archived. Toxicology samples will be frozen and stored until they are sent to an approved laboratory for analysis.

Aerial surveys will be conducted during pupping in June and molting in September along a previously established trend count route (Calkins and Pitcher 1984; Pitcher 1986, 1989) that covers 25 haulout sites and includes 6 sites impacted by the EVOS (Agnes, Little Smith, Big Smith, Seal and Green islands, and Applegate Rocks), 16 unoiled sites, and 3 intermediate sites that were not physically oiled but were adjacent to oiled areas. Visual counts will be made of seals at each site and photographs taken of large groups for later verification.

During June, separate counts will be made of pups and non-pups. Pupping surveys are needed in 1990 and should be done in 1991 since there are no historical data available from PWS during the pupping season with which to compare the 1989 results. Breeding and embryo implantation for 1990 pups occurred while seals were still exposed to oil on haulouts and while hydrocarbon levels in tissues may have been abnormally high.

Surveys during the molt in 1990 and possibly 1991 are necessary to determine whether observed changes in the number of seals on oiled sites between 1988 and 1989 persist.

All statistical tests for significance will use alpha = 0.05. Statistical testing is not appropriate for all objectives. The assessment of cause of death of animals found in areas impacted by the EVOS (Objective A) will require expert evaluation of limited and varying toxicology and histopathology data sets.

Toxicological results for each seal collected will be entered into a data base along with information on date and location of collection; presence of oil in the area; degree of external oiling of the seal; age, sex, size, and reproductive condition. Hydrocarbon levels in the tissues will be tabulated by individual and by groups based on age, sex, collection location, and degree of oiling. Differences between groups will be tested where possible using ANOVA (Neter and Wasserman 1974).

Types of pathology detected will be listed for each specimen and will be grouped into tables by sex, age, collection location, and degree of oiling. Incidence of pathology will be expressed as the percentage of the total number of animals in the group that exhibited a particular type of anomaly. Incidence of pathology will be evaluated in light of toxicological results for each specimen.

Harbor seal surveys must be conducted within biological time windows imposed by the pupping and molting periods. While results of previous harbor seal trend counts have indicated that it is desirable to obtain 7-10 counts during a survey period (Pitcher 1986, 1989), the actual number of counts is frequently limited by the number of days suitable for flying. During pupping, the survey window cannot be extended to accommodate sample size needs since, as pups grow and are weaned, they become increasingly difficult to differentiate from adults when observed from the air. Similarly, during the molt it is necessary to confine surveys to the period when maximum numbers are thought to haul out.

Aerial surveys of harbor seals do not estimate the total number of seals present since they do not account for seals that are in the water or seals hauled out at locations not on the trend count route. Surveys provide indices of abundance based on the number of hauled out seals counted on the trend count route. Interpretation of trend count surveys relies on the assumption that counts of harbor seals on select haulout sites are valid linear indices of local abundance. We assume that within a given biological window, such as the pupping or molting period, haul out behavior remains the same from one year to the next, and counts can thus be compared. Standardization of procedures minimizes the affects of variables such as tide and weather that could influence the number of seals hauled out on a given day.

The trend count route includes haulouts impacted by the EVOS, as well as haulouts that are north, east, and south of the primary area impacted by oil. There is an adequate sample of both oiled and unoiled areas.

There are no historical data on the distribution of harbor seals in PWS during the pupping period. The first surveys during pupping were conducted in June 1989 after the EVOS. In order to gather these data it will be necessary to conduct surveys in at least 1990 and 1991. These data will be used in a retrospective analysis comparing counts of seals in oiled and unoiled sites between years and using the same statistical techniques employed for fall molting surveys (Frost 1990).

Fall molting surveys of the trend count route were conducted in 1983, 1984, 1988, and 1989. The 1984, 1988, and 1989 counts are considered reliable and will be used for comparisons with data collected in 1990 and possibly 1991. Analysis of count data and comparisons to other years will be conducted following statistical methodology used for 1989 molting surveys (Frost 1990).

A repeated measures ANOVA (Winer 1971) will be conducted on the trimean (Hoaglin et al. 1985) of the site count data in order to examine trends in abundance at oiled versus unoiled sites. The trimean statistic will be used as the measure of central tendency because sets of counts at a single location sometimes show bimodal distributions or extreme variations. This analysis assumes random samples, constant variance, and normality of the differences. If necessary, transformations (Snedecor and Cochran 1980) will be used to ensure constant variance and normality. The test assumes that the mean proportion of the population hauled out on the trend count route is constant over years. Hypotheses addressing Objective C will be tested using orthogonal contrasts derived from the ANOVA.

In order to compare pup production at oiled and unoiled sites, a one-way analysis of co-variance (Neter and Wassermann 1974) will be performed on the square roots of the trimeans (Hoaglin et al. 1985) of pup counts, using the square roots of non-pup counts as a covariate. The square root transformation will be used to correct for non-constant variation of the count data (Snedecor and Cochran 1980). Linear contrasts (Neter and Wasserman 1974), where the average number of pups is adjusted to a common number of adults, will be used to test working hypotheses.

BIBLIOGRAPHY

Calkins, D. and K. Pitcher. 1984. Pinniped investigations in southern Alaska:1983:84. Unpubl. Rep. ADF&G, Anchorage, AK 16pp.

Davis, J. E. and S. S. Anderson. 1976. Effects of oil pollution on breeding gray seals. Mar. Poll. Bull. 7:115-118.

Engelhardt, F. R., J. R. Geraci, and T. G. Smith. 1977. Uptake and clearance of petroleum hydrocarbons in the ringed seal, Phoca hispida. J. Fish Res. Board Canada 34:1143-1147

Frost, K. J. 1990. Marine Mammals Study Number 5: Assessment of injury to harbor seals in Prince William Sound, Alaska, and adjacent areas. State-Federal Natural Resource Damage Assessment for April-December 1989. Unpubl. Prelim. Status Rep. ADF&G, Fairbanks, AK. 27pp.

Geraci, J. R., and T. G. Smith. 1976. Direct and indirect effects of oil on ringed seals (Phoca hispida) of the Beaufort Sea. J. Fish. Res. Board Canada 33:1976-1984.

Hoaglin, D. C., F. Mosteller, and J. W. Tukey. 1985. Exploring data tables, trends, and shapes. John Wiley & Sons. New York. 527pp.

Hoover, A. A. 1988. Pacific harbor seal. Pages 125-157 in J. W. Lentfer (ed). Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations. U.S. Marine Mammal Commission, Washington, D.C.

Neter, J., and W. Wasserman 1974. Applied linear statistical models. Richard D. Irwin, Inc., Homewood, Illinois. 842pp.

Pitcher, K. W. 1986. Harbor seal trend count surveys in southern Alaska, 1984. Unpubl. Rep. ADF&G, Anchorage, AK. 10pp.

Pitcher, K. W. 1989. Harbor seal trend count surveys in southern Alaska, 1988. Final Rep. Contract MM4465852-1 to U.S. Marine Mammal Commission, Washington, D.C. 15pp.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical Methods. Iowa State University Press, Ames, Iowa. 507pp.

Winer, B. J. 1971. Statistical principles in experimental design. 2nd Ed. Mcgraw-Hill, New York, New York. 907pp.

BUDGET: NOAA

Salaries	$	82.7
Travel		15.1
Contracts		42.1
Supplies		5.4
Equipment		14.0
Total	$	159.3

MARINE MAMMAL STUDY NUMBER 6A

Study Title: Assessment of the Magnitude, Extent, and Duration of Oil Spill Impacts on Sea Otter Populations in Alaska.

Lead Agency: FWS

INTRODUCTION

In the first year following the EVOS, several hundred sea otters are known to have died as a result of contamination by oil. Death occurred from hypothermia and from severe liver, kidney, and lung damage as a result of ingestion of oil and inhalation of toxic aromatic compounds present during the early period of the spill. Long-term or chronic effects of oil on sea otters are not known, but initial results from the first year's studies indicate sea otter populations have been detrimentally affected. Potential effects may occur as the result of debilitating or sublethal injury, accumulation of toxins, and loss or contamination of the food supply. The capacity of the population to recover to pre-spill levels is not known. This study will assess the impacts of the oil spill on Alaska sea otter populations through (1) surveys of wild populations living in oiled and unoiled areas, (2) genetic, hematological, histopathological and toxicological analysis of tissues collected from live and dead sea otters, (3) analysis of survival, reproduction and movements of adult females and pups living in oiled and non-oiled areas and (4) analysis of population dynamics of dead and living sea otters recovered from or living in oiled and non-oiled areas.

OBJECTIVES

A. BOAT SURVEYS

1. Test that differences in sea otter densities are not significantly different between oiled and unoiled areas.

2. Test for differences in sea otter densities between pre- and post-event surveys in oiled and unoiled areas.

3. Estimate the magnitude of any change between pre- and post-event sea otter population estimates in PWS.

4. Estimate post-event sea otter population size and monitor population trends of sea otters in PWS.

5. Estimate winter 1990 offshore densities of sea otters in oiled and unoiled areas.

B. HISTOPATHOLOGY AND TOXICOLOGY

1. Test the hypothesis that sea otters residing in regions that were not affected by the oil spill have lower levels of hydrocarbons in their visceral fat and whole blood than sea otters residing in areas that were affected by oil.

2. Test the hypothesis that sea otter carcasses found in oiled portions of the Alaska coastline subsequent to the oil spill contain levels of hydrocarbon contamination similar to those in sea otters killed immediately as a result of the spill.

3. Test the hypothesis that sea otter carcasses found in oiled areas subsequent to the spill contain higher burdens of hydrocarbon contaminants than sea otter carcasses found in non-oiled areas or those analyzed before the spill.

4. Evaluate the nature and cause of death of sea otters that died subsequent to the oil spill by performing complete gross and histopathological examinations of carcasses recovered after September 1, 1989.

C. CAPTURE OF ADULT FEMALE AND JUVENILE SEA OTTERS

1. Test the hypothesis that pup survival pre-weaning is not different between oiled and non-oiled areas.

2. Test the hypothesis that weanling survival at various age intervals is not different between oiled and non-oiled areas.

3. Test the hypothesis that survival of adult female sea otters is not different in oiled and non-oiled areas.

4. Test the hypothesis that pupping rates of adult female sea otters are not different between oiled and non-oiled areas.

5. Evaluate the movements of weanling and adult female sea otters with respect to areas in PWS that have been affected by the oil spill.

6. Test the hypothesis that blood values (obtained from complete blood counts and blood panel) do not differ between samples collected from otters from oiled and non-oiled areas.

D. CAPTURE OF ADULT MALE SEA OTTERS

1. Test the hypothesis that blood values (hematogram and chemistry) do not differ among male sea otters living in the oil spill zone and males living in non-oiled areas.

2. Test the hypothesis that variation of DNA content in lymphocytes does not differ among male sea otters living in the oil spill zone and males living in non-oiled areas.

3. Test the hypothesis that DNA structure in sperm cells (measured by the stability of nuclear chromatin) does not differ among male sea otters living in the oil spill zone and males living in non-oiled areas.

4. Test the hypothesis that spermatogenic function, measured by a DNA profile of the testicular cells, does not differ among male sea otters living in the oil spill zone and males living in non-oiled areas.

5. Test the hypothesis that proportion of morphologically normal sperm cells, measured by light microscopy, does not differ among male sea otters living in the oil spill zone and males living in non-oiled areas.

6. Test the hypothesis that levels of hemoglobin adducts, measured by isoelectric focusing and capillary electrophoresis of hemoglobin, do not differ among male sea otters living in the oil spill zone and males living in non-oiled areas.

7. Test the hypothesis that levels of plasma proteins, including haptoglobin, quantified by gel electrophoresis, do not differ among male sea otters living in the oil spill zone and males living in non-oiled areas.

E. ANALYSIS OF POPULATION DYNAMICS BASED ON CARCASSES IN MORGUE

1. Test the hypothesis that the sex and age structure of dead otters recovered during the 5-month period after the oil spill did not differ among various geographic regions and, hence, can be pooled for demographic analysis.

2. Test the hypothesis that age structure of dead otters collected after the spill does not differ from the age structure of otters which died of natural causes before the spill.

3. Assess potential biases in the sample of dead otters collected caused by differential mortality and/or differential probability of carcass recovery.

4. Develop sex and age specific survival schedules that reflect natural survival in the populations prior to the spill.

5. Develop age specific fecundity schedules that reflect natural reproductive rates in the populations prior to the spill.

6. Construct a population model for assessing population recovery in areas affected by the oil spill.

METHODS

BOAT SURVEYS

Surveys will be conducted from small boats manned by an operator and two observers.

A stratified random sampling design, including shoreline, coastal/pelagic and pelagic strata, will be used to meet Objectives A1-5. Approximately 29% of the shoreline and 25% of coastal/pelagic and pelagic transects will be surveyed once in March 1990 and three times (one survey each in June, July and August) during summer 1990 jointly with Bird Study Number 2. All sea otters within transect boundaries will be recorded. The shoreline stratum includes all water within 200 m of any shoreline, and will be surveyed by traveling 100 m offshore, parallel to the coast, at 5-10 knots. The shoreline stratum is divided into transects consistent with those used during 1984-1985 surveys. (Irons et. al., 1988). Sampling strip width and protocols are similar for pelagic surveys.

Strip transect sampling is conducted under the assumption that all sea otters located within the transect are sighted. If this assumption is not met, then population estimates are biased low. If sufficient time and resources are available, an attempt will be made to verify the boat-based observations with concurrent land-based observations during the summer 1990 field season. The sightability assumption is not critical to this study however, since pre-spill observations were not corrected for this factor. Results produced by this study should be considered "estimates of surface abundance" or "population indices" rather than simply "population estimates".

Abundance estimates will be calculated independently for shoreline, coastal and pelagic environments using ratio estimation techniques (Cochran, 1977). Estimates calculated from second-year surveys will be compared to earlier estimates for the determination of injury to the sea otter population within PWS. Differences in otter densities will be tested using two sample t-tests and/or ANOVA, dependent upon post-stratification of oil condition.

HISTOPATHOLOGY AND TOXICOLOGY

Tissue samples for histology will be collected from dead sea otters recovered in or adjacent to habitats affected by oil. Histology samples will be sent to the Armed Forces Institute of Pathology for processing and analysis. For toxicology, duplicate samples of liver, kidney, skeletal muscle, bile and fat will be collected from each sea otter carcass that is recovered from the oil spill zone or areas outside of the oil spill zone that could serve as controls. Collection procedures will follow strict guidelines outlined by the Analytical Chemistry Working Group.

Tissues from carcasses will be graded for degree of necrosis. Mean values for the degree of necrosis will be computed for tissues of sea otters of various age, sex, and location parameters provided sufficient sample sizes exist. Contaminant data from tissues will be stratified by degree of necrosis, and the effect of necrosis will be tested. A comparison of contaminants will also be made between sea otter carcasses found in the oil spill zone and 4 control animals examined in 1986. Data will be checked for normality; if needed, appropriate transformations will be made. Blood values and contaminant values will be compared between treatment and control groups using t-tests or ANOVAs, at $\alpha = 0.05$.

CAPTURE OF ADULT FEMALE AND JUVENILE SEA OTTERS

In addition to sampling dead sea otters, fat and blood will be sampled from free-ranging sea otters residing in areas affected by the oil spill as well as from otters living in non-oiled control areas. The sampling design calls for sampling of blood and fat from a total of 100 reproductively mature females and 100 pups and a total of 100 reproductively mature males. Up to 36cc of blood will be collected from captured animals. At least 4cc of whole blood will be frozen for toxicology, and the remaining blood will be processed as needed for additional assays. From sea otters which are implanted with transmitters, a small (1/2 inch diameter) piece of visceral fat will be removed prior to closing the incision and frozen for toxicology.

The experimental design for the capture and telemetry study takes advantage of the fact that the oil from the EVOS directly covered less than one-half of PWS. That situation has been used to develop a treatment/control study where the portion of PWS that was covered by the spill is the treatment area, and the unaffected portion of eastern PWS, specifically Port Gravina, Port Fidalgo, and Sheep Bay, is the control area.

Intensive studies of sea otters using radio telemetry will concentrate on reproductively mature females and large pups in each area. The pup portion of the study will be initiated in late summer, 1990. The female study was initiated in October 1989 but only 23 females in non-oiled habitat and 9 females in oiled habitat were instrumented. Additional radios will be put on females in spring 1990. Up to 50 reproductively mature females and pups will be instrumented in both the treatment and control areas.

Sea otters will be caught primarily in unweighted tangle nets or dip nets. Tangle nets will be set in areas used by sea otters and anchored at one end. The nets will be monitored closely to prevent captured sea otters from fighting. Captured animals will be removed from the nets and placed in holding cages and transported to a temporary holding cage. Captive sea otters will be fed ad libitum a combination of fresh frozen dungeness crabs and razor clams.

The transmitters will be implanted into the body cavity by a qualified veterinarian. Surgical procedures will follow Williams and Siniff (1983) and Garshelis and Siniff (1983). Transmitters measure 3" x 2" x 1", weigh 120 g, and are coated with an inert material suitable for implantation in sea otters. The transmitters contain a coiled antenna and are powered by batteries that provide an operating life of up to 1,000 days. Following immobilization with a combination of fentanyl citrate and azaperone (Kreeger et al. 1989), abdominal surgery will be performed. During surgery, the animal's status will be monitored by observation of capillary perfusion, color of mucous membranes, respiration rate and depth, and heart rate. While the sea otters are still anesthetized they will be marked with one Temple Tag in each of the flippers and implanted with a passive glass transponder chip (10 mm x 2 mm) injected under the skin in the gluteal area (Thomas et al. 1987). A 30cc blood sample will be taken from each sea otter for blood hemotograms and chemical analyses. A premolar will be removed from each adult for age determination.

After release, attempts will be made to relocate each animal at least bi-weekly from either a boat or airplane. Attribute data for each relocation, including group size, whether or not the focal animals have pups, behavior of focal animal, sea condition, and presence or absence of tags, will be collected. During the pupping season and shortly following that period, efforts will be made to locate reproductively mature females at least weekly.

Following instrumentation, efforts will also be made to locate pups at least weekly. Previous studies have shown relatively high mortality at weaning in normal populations (Monnett, unpublished data). Therefore, frequent relocations of weanlings will increase the chances of recovery of carcasses as soon after death as possible.

All fresh-dead sea otters found in either the treatment or control areas will be sent immediately for necropsy. Samples of tissues for contaminant and histology analysis will be collected.

Alternatives to the implanting of transmitters were considered, including 1) radio tracking devices attached to the outside of the animal, 2) dyes, 3) visual tags attached to flippers, and 4) no marking. External telemetry devices have been tried in the past but are easily damaged by the animal and the environment and have only an average of about 60 days operational time compared to up to 3 years for internal implants. Dyes are not feasible in the marine environment and would adversely affect the animals fur. Temple Tags and a glass transponder chip will be used in conjunction with each implant but by themselves would not allow for the tracking of the animals.

Using standard sample size calculations for testing the difference between two proportions (Snedecor and Cochran, 1967; p. 221), it was determined that a sample size of 50 gives a 79% chance of finding a significant difference at α = .2, given that the population proportion changes by .2 from an initial value of .5. A sample of 50 represents a minimum number at which significant differences between groups might be detected, and the maximum number that can be realistically instrumented and radio tracked.

Reproductive rates are estimated by counting the number of females observed with pups divided by the total number of females. Estimates of survival and reproduction can be calculated over various time intervals.

Reproductive data will be compared between treatment and control areas using contingency tables analysis. Two-way contingency tables will be used except when interactions among age, sex, or location are of interest. In that case three-way or multi-way contingency tables based on log-linear models will be used (Sokal and Rohlf, 1981). Survival estimates will be obtained by the product limit method and differences in survival patterns will be tested with log-rank tests (Pollock et al., 1989).

Data on movements and dispersal will be compared between treatment and control areas. Distance between successive locations, distance between extreme locations and the minimum convex polygon will be calculated for each radio-marked sea otter and stratified by sex, age and reproductive status (Garshelis and Garshelis, 1984; Ralls et al. 1988). Dispersal distance, here defined as the shortest distance between the site of weaning (or the location of the last sighting of females with their pups) and the midpoint of their first established activity center will be compared for sea otter pups.

CAPTURE OF ADULT MALE SEA OTTERS

Proposed approaches to damage evaluation in male sea otters include analysis of blood panels, blood proteins, blood toxin levels, DNA content and structure (in blood lymphocytes, sperm and testis cells), and sperm morphology.

Blood panels (hematograms and chemistry) are a standard diagnostic procedure that will be used. Information on chemical damage will be obtained by examination of blood proteins. Specifically, increased levels of hemoglobin adducts are indicative of chemical exposure (Sabbioni and Neumann, 1990; Tornqvist et al., 1988) and analysis of plasma proteins, with specific examination of haptoglobin binding, can also be of diagnostic value in assessing the health of an individual (Van Pilsum et al., 1986).

Nuclear DNA content of blood lymphocytes is a sensitive indicator of damage to developing cells from clastogenic contaminants in the environment. Cells can be measured by flow cytometry and, for normal samples, the resulting frequency histogram of DNA content should have a very low coefficient of variation. Deviations from the normal DNA content are detected as an increase in the coefficient of variation, reflecting damage to the chromosomes.

Spermatozoa are another cell type in which damage to DNA is readily assayed by flow cytometry (Evenson, 1986). The structural stability of sperm nuclear DNA decreases after exposure to toxic compounds (Evenson, et al., 1985, 1989). The stability of the DNA is inversely related to male fertility (Ballachey et al., 1987; Evenson et al., 1980). Morphology is an alternate indicator of genotoxic damage to sperm cells (Wyrobeck et al., 1983), and thus proportion of normal sperm in samples from otters living in oiled versus non-oiled regions will be compared. Testicular cells will also be collected by fine needle aspiration and examined by flow cytometry to determine proportions of germ cells.

Males will initially be caught in two areas: 1) Western PWS; and 2) Eastern PWS. The first area was directly affected by spilled oil and thus is the treatment area. The latter area will serve as a control. Blood samples, testicular fine needle aspirations (Hendriks et al., 1969; Thorud et al., 1978; Nseys et al., 1984; Sandqvist et al., 1986; B. Purscell, pers. comm.) and electro-ejaculated sperm cells (Salisbury et al., 1978; Howard et al., 1986; Wildt et al., 1989) will be collected from each otter. Following analysis of these samples a decision will be made whether males should be caught in the following three areas: 1) The KP (treatment); 2) Kodiak Island (treatment); and 3) Sitka, in southeast Alaska (control).

It is estimated that a minimum sample size of 18 otters for each control area and 18 otters for each treatment area will be required to give an 80% chance of detecting a significant difference of .10 in the proportion of damaged sperm cells between the groups at α = .05. Twenty animals from each treatment and control area will be sampled.

Blood will be obtained by jugular venipuncture and samples will be handled according to established protocols for the given tests. Complete blood counts and veterinary panels will be done on the blood samples. A subsample of the blood will be allocated for measurement of DNA content of lymphocytes.

An additional subsample of blood will undergo assays for hemoglobin adducts. Plasma protein levels will be quantified. DNA in testis and sperm cells will also be measured. For flow cytometry of sperm cells, samples will be prepared as described for the SCSA by Ballachey et al. (1988). For flow cytometry of the testicular cells, the samples will be prepared as described by Thorud et al. (1980). A premolar will be taken from each otter for age determination. Otters will be tagged and implanted with a transponder chip prior to release.

A one-way MANOVA will be used to test for differences among the geographic groups, using a significance level of $\alpha = .05$. Linear contrasts will be used to make specific comparisons of the groups. Analyses on various subsets of variables will be handled separately (i.e., 1) blood panels, 2) blood DNA/lymphocytes, 3) blood proteins and 4) sperm and testis cells). Toxicology data, when available, will be analyzed in a similar manner. Prior to analysis, the variables to be tested will be examined and transformed as necessary to see that they meet the assumptions of the MANOVA.

ANALYSIS OF POPULATION DYNAMICS BASED ON CARCASSES IN MORGUE

All sea otter carcasses found in the spill zone have been kept in frozen storage. All carcasses not yet examined will be removed from the freezer and thawed. Degree of decomposition and amount of oil on the carcass will be used to subjectively place each animal into one of three categories, killed during the spill due to exposure to oil, died before the spill, and died during the spill but unrelated to oil exposure. Standard body measurements (total length, weight, bacula length) will be recorded for complete carcasses and sex will be determined based on external genitalia or tooth measurements if the carcass is not intact. Sections from a premolar and canine tooth extracted from the skulls of each carcass will be stained and mounted on slides with the age of each dead sea otter estimated to the nearest year by counting the number of cementum lines present (Schneider 1973, Garshelis 1984). Reproductive tracts of all adult females which are not badly decomposed will be examined for implanted fetuses, placental scars, and corpora albicans. Where possible the approximate age and sex of fetuses will also be determined. All data collected on each carcass as well as information available on recovery date and location and comments will be incorporated into a database which will be used for analysis.

The sex and age data will be summarized using a 2 x 3 x 4 contingency table, representing 3 geographic areas (PWS, KP, AP) and 4 age classes (pup, immature, mature, and old). Log-linear analysis will be used to test for differences between area, sex, and age.

The age structure of dead otters collected after the spill in the various geographic areas will be compared to the age structure of otters collected on beaches in PWS prior to the spill (Johnson 1987). Significant post spill increases in prime age animals will be indicative of a major mortality event unrelated to normal mortality processes.

Results from the analysis of age structure will determine if segments of the age structure data should be eliminated from survival rate estimation because of possible sampling biases. From these results the age structures will be constructed for survival estimation using techniques described by Chapman and Robson (1960) and Robson and Chapman (1961). An initial analysis will be performed using all age classes and the model for constant survival. Chi-square tests will be used to test if the model of constant survival adequately fits the data. If constant survival does not appear appropriate, the contribution of each age class to the chi-square statistic will be examined to determine which age classes the assumption of constant survival appears appropriate. The "segment" method (Chapman and Robson 1960) will then be used to estimate annual survival for these age classes. If data from other sources indicates that the assumption of a "stationary" population is not met the survival estimates will be adjusted using estimates of rate of change in the population (Eberhardt 1988). Estimates of the impact of senescence on the survival rates of the oldest age classes will be obtained by using minimum chi-square or nonlinear least square techniques to fit age structure data to the 3-component survivorship model developed by Siler (1979) and modified by Eberhardt (1985). Estimates of the parameters in the survivorship model will then be used to construct an age-specific survival schedule for incorporation into a population model.

Results of the examination of female reproductive tracts and the variability in sizes of fetuses will be used to construct a fecundity schedule. These data will then be fit to Eberhart's (1985) fecundity model using minimum chi-square or nonlinear least square techniques. Estimates of the parameters in the fecundity model will then be used to construct an age-specific fecundity schedule for incorporation into a population model.

A Leslie matrix (Leslie 1945, 1948) type population model will be constructed using the survivorship and fecundity schedules developed from the analysis described in objectives 4 and 5. The stable age distribution will be calculated using Lotka's (1907) equation as modified by Cole (1954) for populations where births are concentrated in a short time interval each year (Eberhardt and Siniff 1988). This stable age distribution will be used to construct an initial population. Population projections will be simulated using a commercial spreadsheet and the fecundity and survival schedules developed from the carcass data. The performance of the simulated population will be compared to data on the general demographic characteristics of the PWS population available from past and current telemetry studies. These comparisons will suggest adjustments to the fecundity and survival schedules and possibly incorporation of density dependent mechanisms into the model. A series of simulation experiments will then be conducted to explore possible recovery patterns of the PWS population following the mortality event caused by the oil spill.

BIBLIOGRAPHY

Ballachey, B.E., D.P. Evenson, and R.G. Saacke. 1988. The Sperm Chromatin Structure Assay: Relationship with alternate tests of semen quality and heterospermic performance of bulls. Jnl. Androl. 9(2):109-115.

Ballachey, B.E., W.D. Hohenboken, and D.P. Evenson. 1987. Heterogeneity of sperm nuclear chromatin structure and its relationship to bull fertility. Biol. Reprod. 36:915-925.

Ballachey, B.E., H.L. Miller, L.K. Jost, and D.P. Evenson. 1986. Flow cytometry evaluation of testicular and sperm cells obtained from bulls implanted with zeranol. Jnl. Anim. Sci. 63:995-1004.

Bickham, J.W., B.G. Hanks, M.J. Smolen, T. Lamb, and J.W. Gibbons. 1988. Flow cytometric analysis of the effects of low-level radiation exposure on natural populations of slider turtles (Pseudemys scripta). Arch. Environ. Contam. Toxicol. 17:837-841.

Chapman, D.G. and D.S. Robson. 1960. The analysis of a catch curve. Biometrics 16:354-368.

Cochran, W.G. 1977. Sampling Techniques. John Wiley and Sons, Inc. New York, New York. 428pp.

Cole, L.C. 1954. The population consequences of life history phenomena. Quarterly Review of Biology. 29:103-137.

Eberhardt, L.L. 1985. Assessing the dynamics of wild populations. J. Wildl. Manage. 49:997-1012.

Eberhardt, L.L. 1988. Using age structure data from changing populations. J. Applied Ecology 25:373-378.

Eberhardt, L.L. and D.B. Siniff. 1988. Population model for Alaska Peninsula sea otters. Minerals Management Service, 88-0091. 94pp.

Evenson, D.P. 1986. Flow cytometry of acridine orange stained sperm is a rapid and practical method for monitoring occupational exposure to genotoxicants. Pp. 121-132 in: Monitoring of Occupational Genotoxicants, M. Sorsa and H.

Norppa, eds. New York, Alan R. Liss Inc.

Evenson, D.P., R.K. Baer, and L.K. Jost. 1989. Long-term effects of triethylenemelamine exposure on mouse testis cells and sperm chromatin structure assayed by flow cytometry. Envir. Molec. Mutagen. 14:79-89.

Evenson, D.P., Z. Darzynkiewicz, and M.R. Melamed. 1980. Relation of mammalian sperm chromatin heterogeneity to fertility. Science 240:1131-1133.

Evenson, D.P., P.H. Higgins, D. Grueneberg, and B.E. Ballachey. 1985. Flow cytometric analysis of mouse spermatogenic function following exposure to ethylnitrosourea. Cytometry 6:238-253.

Evenson, D.P. and M.R. Melamed. 1983. Rapid analysis of normal and abnormal cell types in human semen and testis biopsies by flow cytometry. J. Histochem. Cytochem. 31:248-253.

Fienberg, S.E. 1980. The analysis of cross-classified categorical data. 2nd edition, MIT Press, Cambridge, MA. 198pp.

Garshelis, D.L. 1984. Age estimation of living sea otters. J. Wildl. Manage. 48:456-463.

Garshelis, D.L. and D.B. Siniff. 1983. Evaluation of radiotransmitter attachments for sea otters. Wildl. Soc. Bull. 11:378-383.

Garshelis, D.L. and J.A. Garshelis. 1984. Movements and management of sea otters in Alaska. J. Wildl. Manage. 48:665-678.

Garshelis, D.L., J.A. Garshelis, and A.T. Kimker. 1986. Sea otter time budgets and prey relationships in Alaska. J. Wildl. Manage. 50(4):637-647.

Hendricks, F.B., P.A. Lambird, and G.P. Murphy. 1969. Percutaneous needle biopsy of the testis. Fertil. Steril. 20:478-481.

Howard, J.G., M. Bush, and D.E. Wildt. 1986. Semen collection, analysis and cryopreservation in non-domestic mammals. In: Current Therapy in Theriogenology, pp. 1047-1053. Ed. D. Morrow. W.B. Saunders Co., Philadelphia.

Irons, D.B., D.R. Nysewander, and J.L. Trapp. 1988. Prince William Sound sea otter distribution in relation to population growth and habitat type. U.S. Fish and Wildlife Service. Unpubl. report. 31pp.

Jameson, R.J. and A.M. Johnson. 1987. Reproductive characteristics of female sea otters. Unpublished manuscript.

Johnson, A.M. 1987. Sea Otters of Prince William Sound, Alaska. Unpubl. Report, U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center, Anchorage, AK.

Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. North Am. Fauna No. 68. 352pp.

Kreeger, T.J., C. Monnett, L.M. Rotterman, and A.R. DeGange. 1989. Chemical immobilization of Sea Otters (Enhydra lutris). Unpubl. manuscript.

Lensink, C.J. 1962. The history and status of sea otters in Alaska. Ph.D. Thesis, Purdue Univ., Lafayette, IN. 186pp.

Leslie, P.H. 1945. On the use of matrices in certain population mathematics. Biometrika 33:183-212.

Leslie, P.H. 1948. Some further notes on the use of matrices in population mathematics. Biometrika 35:213-245.

Lotka, A.J. 1907. Relation between birth and death rates. Science, N.S. 26:21-22.

McBee, K. and J.W. Bickham. 1988. Petro-chemical related DNA damage in wild rodents detected by flow cytometry. Bull. Environ. Contam. Toxicol. 40:343-349.

Nseyo, U.O., L.S. Englander, R.P. Huben, and J.E. Pontes. 1984. Aspiration biopsy of testis: another method for histologic examination. Fertil. Steril. 42:281-284.

Pollock, K.H., S.R. Winterstein, C.M. Bunch, and P.D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53: 7-15.

Ralls, K., T. Eagle, and D.B. Siniff. 1988. Movement patterns and spatial use of California Sea otters. In D.B. Siniff and K. Ralls (eds.), Population Status of California Sea Otters. OCS Study MMS 88-0021, USDI, Minerals Manage. Serv. pp. 33-63.

Robson, D.S. and D.G. Chapman. 1961. Catch curves and mortality rates. Trans. Amer. Fish. Soc. 90:181-189.

Sabbioni, G. and H.-G. Neumann. 1990. Biomonitoring of arylamines: hemoglobin adducts of urea and carbamate pesticides. Carcinogenesis 11:111-115.

Sandqvist, C., A. Lukola, and M. Parvinen. 1986. Testicular aspiration biopsy in evaluation of fertility of mink, Mustela vison. Jnl. Reprod. Fertil. 77(2):531-536.

Schneider, K.B. 1973. Age determination of sea otters. Final Report, Fed. Aid. Wildl. Restor. Proj., W-17-4, W-17-5. 23pp.

Siler, W. 1979. A competing-risk model for animal mortality. Ecology 60:750-757.

Siniff, D.B. and K. Ralls. 1988. Reproduction, survival and tag loss in California Sea otters. In D.B. Siniff and K. Ralls (eds.), Population Status of California Sea Otters. OCS Study MMS 88-0021, USDI, Minerals Manage. Serv. pp. 13-32.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods, 6th Ed. Iowa State University Press, Ames.

Sokal, R.R. and F.J. Rohlf. Biometry. Second Edition. W.H. Freeman & Co., San Francisco, CA. 859 pp.

Thomas, J.A., L.H. Cornell, B.E. Joseph, T.D. Williams, and S. Dreischman. 1987. An implanted transponder chip used as a tag for sea otters (Enhydra lutris). Marine Mammal Science 3(3):271-274.

Thorud, E., O.P.F. Clausen, and T. Abyholm. 1980. Fine needle aspiration biopsies from human testes evaluated by DNA flow cytometry. Flow Cytometry IV, pp 175-177, Universitetsforlaget.

Tornqvist, M., A. Kautiainen, R.N. Gatz, and L. Ehrenberg. 1988. Hemoglobin adducts in animals exposed to gasoline and diesel exhausts. 1. Alkenes. Jnl. Applied Toxic. 8(3):159-170.

Van Pilsum, J.F., R.J. Roon, and M.H. Koenst. Electrophoresis of Blood Proteins. In Medical Biochemistry: Principles and Experiments, J.F. Van Pilsum and R.J. Roon, Eds. Univ. of Minnesota Press, 1986.

Wildt, D.E., M. Bush, C. Morton, F. Morton, and J.G. Howard. 1989. Semen characteristics and testosterone profiles in ferrets kept in a long-day photoperiod and the influence of HCG timing and sperm dilution medium on pregnancy rate after laparoscopic insemination. Jnl. Reprod. Fertil. 86(1):349-358.

Williams, T.D. and D.B. Siniff. 1983. Surgical implantation of radiotelemetry devices in the sea otter. J. Am. Vet. Med. Assoc. 183:1290-1291.

Wyrobek, A.J., L.A. Gordon, J.G. Burkart, M.W. Francis, R.W. Kapp Jr., G. Letz, H.V. Malling, J.C. Topham, and M.D. Wharton. 1983. An evaluation of the mouse sperm morphology test and other sperm tests in non-human mammals: A report of the U.S. Environmental Protection Agency Gene-Tox Program. Mutat. Res. 115:1-72.

MARINE MAMMAL STUDY 6B

Study Title: Pre to Post Spill Comparisons of Sea Otter Mortality in PWS Following the EVOS

INTRODUCTION

Much of the initial work to determine injury to sea otters caused by the EVOS focused on readily observable signs of acute injury. Efforts have since shifted toward studies to identify possible long term effects due to acute or chronic exposure to hydrocarbons in the environment. Changes in the characteristics of mortality (ie. mortality rates, age and sex composition of mortality) from pre to post spill time periods may be indicative of reduced viability of sea otters exposed to oil or hydrocarbon residues in the environment.

Work by Kenyon (1969) and Johnson (1987) documented patterns of mortality for sea otter populations within areas at various stages of reoccupation. Their findings indicate extremely low levels of mortality for prime age otters.

The Green Island area in southwestern PWS has a well established otter population and is within the oil spill zone. Johnson's study provides 10 years of base line mortality data for this area as well as 10 years of mortality data for the more recently established populations in the non-oiled, northeastern portion of PWS. Using the same beach survey methods as Johnson (1987) this study will seek to determine if the overall characteristics of mortality have changed from pre spill levels for both oiled and non-oiled habitats.

OBJECTIVES

A. Test the hypothesis that post-spill levels of mortality (number of carcasses per linear kilometer of beach surveyed) are not different from pre-spill levels of mortality in PWS.

B. Test the hypothesis that the proportion of prime age carcasses found on beaches in post-spill surveys is not significantly different from proportions found in pre-spill beach surveys in PWS.

C. Test the hypothesis that the proportion of female carcasses found on beaches in post-spill surveys is not different from proportions found in pre-spill beach surveys in PWS.

METHODS

Sampling Methods

For valid comparisons, beaches surveyed and methods used will be the same as those used by Johnson (1987). Treatment beaches to be surveyed will include those on Green Island, Little Green Island, Channel Island, and the barrier islands northwest of Gibbon Anchorage on Green Island. Control beaches will include those in the Hell's hole, Olsen Bay area of Port Gravina in the northeast portion of PWS. These beaches will be walked once during April or May before summer revegetation occurs which may hide old carcasses washed high on the beach.

Skulls will be taken from carcasses and a tooth extracted for aging (Garshelis 1984). Any fresh carcasses collected will be necropsied as soon as possible and tissue samples for toxicology and histopathology will be collected. Badly decomposed carcasses or partial remains may have no evidence indicating the sex of the individual. In these cases, if a canine tooth is present and the carcass is that of an adult, sex may be determined by canine diameter (Johnson 1987, Lensink 1962).

All teeth will be sectioned and prepared according to standard procedures. Teeth will be read (aged) separately by two experienced readers with no knowledge of where the tooth was collected or other information on the carcass. Necropsies will be performed and histopathology samples will be prepared and analyzed according to standard protocols.

DATA ANALYSIS

Levels of mortality for a given year using beach survey data are influenced by a number of variables (ie. weather and current patterns, yearly changes in otter distribution and abundance) and are variable (2 to 34 carcasses found in any one year on Green Island area beaches). However multiple years data with associated variance will provide a basis for comparing pre and post spill mortality levels. To do so, only those beaches providing at least five years of pre spill data will be resurveyed for comparisons. A mean number of carcasses per kilometer of beach will be calculated for each pre spill year in both areas of PWS and for post spill data as they are collected.

The proportion of prime age otter carcasses will be calculated for each year. Prime age in this study refers to those age groups with uniformly high survival rates as measured by pre spill data. Based on Johnson (1987), prime age are animals between 2 and 8 years old in the Green Island area and those between 2 and 10 years in the Port Gravina area.

The proportion of female otters will be calculated for each year.

Changes in these proportions could reflect changes in the proportions of males and females in the area due to immigration/emigration or initially high mortality of one group at the time of the spill. Changes may also reflect differential levels of chronic mortality between sexes due to unequal levels of susceptibility to hydrocarbon toxins or unequal levels of exposure to toxins because of spatial segregation.

These three variables will be analyzed separately for the two areas. Pre spill data represent the control in this study and post spill data represent the treatment observations. Analysis will be a t-test using years as replicates for each dependent variable. In the case of the first post spill year's analysis the variance will be estimated entirely from pre-spill data.

The most sensitive indicator of abnormal change in mortality will be the proportion of prime age carcasses found. This variable is not influenced by many of the confounding variables associated with the other two and a significant change in this parameter is the most meaningful biologically.

A summary of Johnson's pre spill mortality data for the Green Island area shows the proportion of prime age carcasses relative to total carcasses found on beaches to range from 0.0 to 0.28 with a 9 year average of 0.12 (n = 163 carcasses, SD = 0.094). Assuming post spill variability to be the same, a proportion of 0.32 or greater in the first post spill year would represent a significant increase in post spill, prime age mortality at $\alpha = 0.20$. A proportion of 0.51 would represent a significant increase at $\alpha = 0.05$.

BIBLIOGRAPHY

Garshelis, D. L. 1983. Age estimation of living otters. J. Wildlife Manage. 48(2):456-463.

Johnson, A. M. 1987. Sea otters of Prince William Sound, Alaska Unpublished Report, U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center, Anchorage, AK.

Kenyon, K. W. 1969. The sea otter in the eastern Pacific Ocean. North Amer. Fauna 68. 352 pp.

Lensink, C. J. 1962. The history and status of sea otters in Alaska. Ph.D. Thesis, Purdue Univ. 188 pp.

MARINE MAMMAL STUDY NUMBER 6C

Study Title: A Drift Study To Assess The Fate and Recovery of Sea Otter Carcasses In PWS.

INTRODUCTION

Four hundred and ninety sea otter carcasses were recovered from PWS during the EVOS response. Based on information from the rehabilitation effort and the recovery of carcasses throughout the spill zone, it is likely that more sea otters were killed in PWS than in any other area affected by the oil spill. There are no data to indicate what proportion of the sea otter carcasses from PWS stayed within or drifted out of PWS and were lost or recovered elsewhere.

OBJECTIVE

Determine whether simulated sea otter carcasses (floats) deployed in PWS remain in or drift out of the Sound.

METHODS

Thirty simulated sea otter carcasses (floats) will be designed for the study. Design of the floats is crucial because the float must have drift characteristics similar to a sea otter carcass. Each float will be marked with a visible tag containing the address and phone number of the FWS should one of the floats be recovered. In addition, each float will contain a small radio transmitter with an external whip antenna that has an operating life 40-50 days. Floats will be deployed by boat in sea otter habitat affected by the oil spill in PWS. Ten floats will be deployed in PWS in three consecutive releases. If feasible, deployment of ten simulated otter carcasses will be concurrent with the ongoing drift study, "An Assessment of Damage to Seabirds in PWS and the Western GOA Resulting from the EVOS."

Following release, the simulated carcasses will be relocated using fixed-wing aircraft outfitted with 2 4-element yagi antennas and a telemetry receiver. Up to 8 hours per day for 25 days will be devoted to tracking the floats during the drift experiment. Within PWS fixed-wing aircraft will fly parallel to the shoreline at an elevation of 1500 ft. A systematic search pattern will be developed for offshore areas within the Sound. Outside of the PWS the aircraft will fly at 3,000 ft over open water following a systematic search pattern. The aircraft periodically will search the coastline of the KP. Relocations will be marked directly on detailed charts or topographic maps of the study area and entered into the computer as UTM coordinates.

Information on the recovery locations of sea otter carcasses from Prince William Sound and the Kenai Peninsula during the oil spill response will be used to estimate recovery rates.

Recovery locations for simulated sea otter carcasses deployed in PWS will be stratified into two groups: recoverable (on shore or within 200 m of shore) or nonrecoverable (> 200 m off shore in the Sound or outside of PWS). Floats that remain offshore or that are not found will be considered unrecoverable. The overall recovery rate of simulated carcasses in PWS will be estimated as the proportion of carcasses that drift into habitat in which they could have been recovered.

BUDGET: FWS

	6A	6B	6C	Total
Salaries	$ 389.8	5.0	0	$ 394.8
Travel	41.0	2.6	0.8	44.4
Contractual	422.3	1.0	24.7	448.0
Commodities	153.6	1.6	0.6	155.8
Equipment	53.8	0.8	7.4	62.0
Total	$ 1,060.5	11.0	33.5	$1,105.0

MARINE MAMMAL STUDY NUMBER 7

Study Title: Assess the Fate of Sea Otters Oiled and Rehabilitated as a Result of the EVOS

Lead Agency: FWS

INTRODUCTION

The capture, cleaning, and care of sea otters contaminated with oil during the EVOS oil spill has been the focus of considerable attention and effort. During the initial weeks of the spill, the health of many of the sea otters brought to the cleaning center in Valdez was severely compromised by exposure to the oil, and many died. The chronic effects of exposure to oil on otters which survived and were released into the wild are unknown. Given that the underlying goal of the rehabilitation program was to release sea otters back into the wild as functioning members of their environment, it was important that a long-term evaluation of the process be undertaken. This information will assist in guiding future cleaning operations for sea otters as well as aiding our understanding of how exposure to crude oil from the EVOS affected sea otters. Forty-five rehabilitated sea otters were implanted with radio transmitters in summer 1989 and released shortly thereafter in eastern PWS. Radio tracking of those individuals is ongoing. Twelve of the instrumented sea otters are known dead; several others are missing. Preliminary evidence suggests that mortality of rehabilitated sea otters is higher than a sample of animals instrumented in eastern PWS as a control.

OBJECTIVES

A. Test the hypothesis that survival of sea otters that underwent oiling, cleaning, rehabilitation and release is not different from that of sea otters that were not affected by the oil spill.

B. Test the hypothesis that survival of rehabilitated sea otters that re-enter oiled areas does not differ significantly from that of rehabilitated sea otters that remain in oil free areas.

C. Test the hypothesis that reproductive rate of female sea otters that underwent oiling, cleaning and rehabilitation does not differ significantly from that of female sea otters that were not affected by the oil spill.

D. Document the movements of rehabilitated sea otters relative to impacted habitat in western PWS and the KP.

METHODS

Sampling Methods

Thirty-six of the instrumented sea otters were from the KP, either from the Valdez, Seward, or Homer sea otter facilities. The remaining nine implanted otters were from PWS. Comparisons of effects of severity of oiling as well as the effects of fresh crude oil vs. weathered crude oil on survival of sea otters released back into the wild were intended; however, because only nine sea otters oiled in PWS with fresh crude oil were suitable for implantation, analyses comparing the effects of oil type and degree will be limited.

Forty-five rehabilitated sea otters were instrumented prior to release. A sample of 50 female sea otters from non-oiled areas instrumented as part of Marine Mammal Study Number 6 (M/M) will serve as control. Twenty-three control animals were instrumented in eastern PWS during fall 1989. Additional animals will be instrumented this spring as part of the control group. An existing population of 58 radio-marked sea otters in the vicinity of the release sites for the rehabilitated sea otters is also available for comparison. For specifications on the transmitters and the implant protocol see the study proposal for M/M Study 6.

Using standard sample size calculations for testing the difference between two proportions (Snedecor and Cochran, 1967; p. 221), a sample size of 45 gives a 75% chance of finding a significant difference at alpha = 0.20, given that the population proportion changes by .2 from an initial value of .5.

All sea otters used in this study were released back into the wild in eastern PWS as recommended in the FWS Draft Release Strategy Plan for Rehabilitated Sea Otters. The release sites were not directly affected by oil from the spill and were occupied by sea otters prior to the release. Male sea otters were released in a male area in Nelson Bay. Females were released in a female area in Sheep and Simpson bays. The release sites represent a short to moderately long translocation for sea otters captured in western PWS and along the KP.

After the initial 20 day monitoring period, the frequency of relocation has depended upon weather, and the sex, age, reproductive status, and whereabouts of the marked animals. Relocations of all animals were intended to be made at least biweekly but for many of the animals, movements have been erratic and unpredictable, therefore they have been difficult to relocate. During the pupping season and shortly following that period attempts will be made to locate reproductively mature females at least weekly although this will be impossible for some animals. Those animals captured on the KP and that have returned to the KP have only been relocated occasionally.

Attribute data for each relocation, including group size, number of pups in the group, whether or not the focal animals had a pup, and behavior of focal animal, are also collected. At the end of each workday, locations of each otter are entered directly into a computer along with the attribute data. Periodically, those data are transferred to Anchorage, where they will be analyzed using geoprocessing software and statistical software, including SAS. In addition to location fixes, qualitative assessments of the health status of each rehabilitated sea otter are being made.

Marked sea otters that have died following release are collected as soon as possible. Carcasses that are in suitable condition are necropsied. Tissue samples will be taken for histology and toxicology.

Additionally, histopathological samples taken from sea otters that died in the rehabilitation centers will be analyzed. Results will be important for analyzing the effectiveness of current rehabilitation techniques, for assessing the need for changes in these techniques and for providing other information important for future sea otter restoration efforts.

Estimates of survival rate of the rehabilitated sea otters will be calculated for comparison with those of control animals and other populations of sea otters within and outside of Alaska.

Survival estimates will be obtained by the product limit method and differences in survival patterns will be tested with log-rank tests (Pollock et al., 1989).

Reproduction and movements of rehabilitated, implanted and control sea otters will also be examined in the proposed study. The reproductive rate will be estimated for each population by counting the number of females in each group (rehabilitated and controls) observed with a pup, and dividing this value by the total number of females observed. However, given the small sample sizes of females, sufficient data to examine reproductive rates in a rigorous statistical sense may not be available. Several measures will be used in the analysis of movements including distance between successive locations, minimum convex polygon, and distance between extreme locations (Garshelis and Garshelis 1984, Ralls et al. 1988). Since many of the sea otters that make up the radio telemetry portion of this study were originally captured on the KP and in western PWS, the release sites represented a short to moderate translocation. The influence of translocation distance on movements of sea otters will be examined by regressing translocation distance on the daily rate of movement or on dispersal distance. Dispersal distance is defined as the distance from point of release to the location of the translocated sea otter's first activity center at which it becomes sedentary.

BIBLIOGRAPHY

Garshelis, D.L. and J.A. Garshelis. 1984. Movements and management of sea otters in Alaska. J. Wildl. Manage. 48:665-678.

Kleinbaum, D.G. and L.L. Kupper. 1978. Applied Regression Analysis and Other Multivariable Methods. Duxbury Press/Wadsworth Publishing Co., Belmont, California.

Pollock, K.H., S.R. Winterstein, C.M. Bunch, and P.D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53: 7-15.

Ralls, K., T. Eagle, and D.B. Siniff. 1988. Movement patterns and spatial use of California Sea otters. In D.B. Siniff and K. Ralls (eds.), Population Status of California Sea Otters. OCS Study MMS 88-0021, USDI, Minerals Manage. Serv. pp. 33-63.

Siniff, D.B. and K. Ralls. 1988. Reproduction, survival and tag loss in California Sea otters. In D.B. Siniff and K. Ralls (eds.), Population Status of California Sea Otters. OCS Study MMS 88-0021, USDI, Minerals Manage. Serv. pp. 13-32.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. 6th Edition. The Iowa State University Press, Ames, IA.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. 2nd Edition. W.H. Freeman and Co., San Francisco.

BUDGET: FWS

Personnel	$	42.5
Travel		5.0
Contractual		87.6
Commodities		11.0
Equipment		0.9
Total	$	147.0

TERRESTRIAL MAMMAL INJURY ASSESSMENT

Terrestrial mammals are an important part of the ecosystem in the area affected by the EVOS. A wide variety of species are present, many of which use intertidal habitats that were heavily impacted by oil. They are important to humans for recreational viewing, sport and subsistence hunting, and commercial and subsistence trapping.

In the 1989 damage assessment plan, 19 terrestrial mammal species were identified as potentially being impacted by oil. Of those, five were selected for intensive field study and nine were chosen for general assessment only. In 1990, intensive damage assessment studies in the field will be continued for three species: deer, river otter, and brown bear. A literature review will also be completed to gather information on the importance of intertidal habitat use by black bear.

The deer study will focus on detection of lethal injury during the spring of 1990 when deer are concentrated on beaches and, therefore, most likely to come in contact with oil. If no mortality attributed to oil is detected, this project will be discontinued. The river otter and brown bear studies will explore both lethal and sublethal injury. The river otter study includes examination of animals found dead and assessment of oil impacts on populations, food habits, and habitat use. The brown bear project will examine mortalities and assess impact on reproduction and population density

A laboratory study to determine the influence of hydrocarbons on reproduction in ranched mink will also be conducted. It commenced in 1989 and will end in July 1990. The work will provide information on whether sublethal doses of hydrocarbons will influence reproduction in mammals. Mink will provide a model for other related terrestrial and marine mammal species.

TERRESTRIAL MAMMAL STUDY NUMBER 1

Study Title: Assessment of the Effect of the EVOS on the Sitka Black-tailed Deer in PWS and the Kodiak Archipelago

Lead Agency: ADF&G

INTRODUCTION

Sitka black-tailed deer (Odocoileus hemionus sitkensis) are the most abundant large mammal on the islands of PWS and the Kodiak Archipelago. ADF&G wildlife biologists estimate that there are 15,000 to 20,000 deer in PWS and up to 100,000 deer on the Kodiak Archipelago. In addition to the intrinsic values of this resource, it also has a substantial economic value to residents of Alaska.

During late winter and early spring, deer in PWS and Kodiak usually concentrate on beaches and along a relatively narrow fringe near the coast (ADF&G 1986). Groups of over 500 deer have been observed on some beaches. These areas commonly have a reduced snow depth or are snow-free, and deer forage on intertidal marine vegetation, coastal sedges, grasses, shrubs, and herbaceous vegetation in the forest understory (ADF&G 1986).

Hinchinbrook, Montague, and Hawkins Islands contain most of the deer habitat in PWS. Beaches on Hinchinbrook and Hawkins Islands generally were not effected by the EVOS, whereas the northern portion of Montague Island was lightly oiled. Deer also occur in relatively high densities on some of the other islands in PWS that were heavily impacted by oil. Deer are abundant throughout the Kodiak Archipelago. Light to very light EVOS impacts were reported along most Kodiak beaches, with heaviest concentrations occurring on the east side of Shuyak Island and along portions of Uyak Bay on Kodiak island.

Oil has affected several types of coastal deer forage, and deer have been observed feeding on oiled kelp. It is anticipated that deer will be adversely affected if they consume vegetation that has been contaminated by oil. Small to moderate amounts of crude oil consumed by deer and other ruminants may cause direct mortality due to disruption of the rumen fermentation process and aspiration of rumen fluid into the lungs (Rowe et al. 1972). Sublethal injury also could occur, reducing animal health and affecting reproduction.

When oil reached beaches where deer were concentrated in late March/April 1989, snow was already melting in upland areas. Some deer had begun their annual spring movements away from the coast and into higher elevations. This fact, coupled with the substantial increase in human activity on beaches soon after the spill undoubtedly reduced the potential for deer exposure to oil. However, the increased human activity probably pushed some deer away from preferred beach feeding areas prematurely, forcing them into areas with deeper snow. This would cause accelerated mortality because the energy reserves of deer are at an annual low state during late winter/early spring. Unfortunately, quantification of such additional indirect "natural" mortality was not possible. The winter and spring of 1989-90 may be the best time to investigate potential impacts of oil on wintering deer. If winter temperatures and snowpacks are within normal limits, deer will concentrate along beaches sometime in the mid-December to mid-February period and human activity will be far less than it was from late March through late fall 1989.

OBJECTIVES

A. Test the hypothesis that deer on heavily oiled islands have tissues and rumen contents that have been contaminated by oil.

B. Test the hypothesis that deer found dead have rumen contents in their lungs.

C. Estimate the number of dead deer per unit area on both a heavily oiled and a non-oiled island in the Sound, if substantial numbers of deer concentrate on oiled beaches in the late winter of 1989-90, and there is evidence to suggest that some of these deer are dying from oil contamination.

METHODS

A sample of live deer has been collected and examined for hydrocarbon contamination. Deer were collected in areas near beaches in PWS and the Kodiak Archipelago that had been affected by oil. These collections occurred during various periods throughout the year.

Deer were collected on Afognak Island on 7 April 1989, prior to any reported EVOS impacts in the area. Tissue samples were collected, wrapped in Reynolds aluminum foil and frozen for histopathological analysis.

Deer near oiled beaches on Shuyak Island were taken on 4 May 1989. Necropsies were conducted by a pathologist immediately after collection and tissue samples were collected for histopathology and hydrocarbon analysis. Additional deer on Shuyak and from PWS were taken near oiled beaches from 31 May through 15 June 1989. Gross necropsies were performed in the field by wildlife biologists and tissue samples were collected for histopathology and hydrocarbon analysis.

Live deer were collected in oiled areas or areas that are known to be heavily used by deer hunters in PWS and the Kodiak Archipelago during August and September 1989. Gross necropsies were performed in the field by wildlife technicians and tissue samples were collected for future histopathology and hydrocarbon analysis. Small amounts (approx. 2 cm^2) of liver and skeletal muscle from each animal were boiled, smelled and tasted in an attempt to detect obvious evidence of oil contamination.

Additionally, several samples were made available for analysis from dead deer collected by ADF&G staff on or near oiled beaches in PWS in April, and from deer found dead and turned in by various workers associated with the EVOS throughout the spring and summer of 1989.

Flights will be made over selected beaches in PWS as often as possible, but not more frequently than every two weeks during the winter of 1989-90. If information obtained during these flights, or observations from individuals in the field indicate that deer are concentrating on oiled beaches, additional deer collections will be made and searches conducted for dead deer in those areas. If deer behavior, gross necropsy, and examination of lungs suggest that deer are dying from oil, systematic surveys will be conducted on a heavily oiled island and a control island of similar size, topography, and deer density. The carcass of each dead deer that is found will be examined in the field by a biologist and recent mortalities will be examined by a pathologist. Pellet group counts on each island will be done to correct for different deer densities (Kirchhoff and Pitcher 1988a, Kirchhoff and Pitcher 1988b). If it is assumed that deer carcasses are distributed in a "patchy fashion", a systematic sampling scheme should be close to optimal (Snedecor and Cochran 1980) and this procedure will provide an estimate of deer mortality per unit area on each island.

Throughout all phases of this study we will attempt to identify potential alternative methods and strategies for restoration of lost use, populations, or habitat if injury is identified. The final report will include a listing of suggested ways to address long-term restoration projects.

Tissues which were collected will be analyzed as outlined by the EVOS Histopathological Technical Group and the Hydrocarbon Technical Group. All statistical analyses will be performed at an alpha level of 0.05. Sample sizes will be used that are adequate to detect at least 1 deer affected by oil contamination with a given percentage of certainty, for varying proportions of the population contaminated by hydrocarbons. These sample size calculations are based on a binomial distribution (Mendenhall, Schaffer and Wackerly 1981), and assume that the sample size is very small compared to the population total. This study will assume that at least 10% of the deer population was affected by

EVOS; therefore, a total sample of at least 29 deer will be collected to be 95% certain of collecting at least one deer affected by hydrocarbons.

BIBLIOGRAPHY

Alaska Department of Fish and Game. 1986. Alaska Habitat Management Guide - Life Histories and Habitat Requirements of Fish and Wildlife. Ak. Dept. Fish and Game. 763pp.

Kirchhoff, M.D. and K.W. Pitcher. 1988a. Evaluation of methods for assessing deer population trends in southeast Alaska. Fed. Aid Wildl. Res. Prog. Rep. W -22-6. Job 2.9. 13pp.

Kirchhoff, M.D. and K.W. Pitcher. 1988b. Deer pellet-group surveys in southeast Alaska, 1981-1987. Fed. Aid Wildl. Res. Prog. Rep. W-22-6. Job 2.9. Objective 1. 13pp.

Mendenhall, W., R.L. Schaffer, and D.D. Wackerly. 1981. Mathematical Statistics with Applications. Duxbury Press. Boston, Mass. 686 pp.

Rowe, L.D., J.W. Dollahite, and B.J. Camp. 1972. Toxicity of two crude oils and of kerosine to cattle. J. Amer. Vet. Med. Asso. 162(2):61-66.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical Methods; Seventh Edition. Iowa St. Univ. Press. Ames, Iowa. 507 pp.

BUDGET: ADF&G

Personnel	$ 60.6
Travel & per diem	4.0
Contracts & Services	52.0
Supplies	8.0
Equipment	0.0
TOTAL	$ 124.6

TERRESTRIAL MAMMAL STUDY NUMBER 2

Study Title: Review of Literature on Intertidal Habitat Use by Black Bear

Lead Agency: ADF&G

INTRODUCTION

There is a dense population of black bear (Evarctos americanus) in PWS. They are omnivorous, opportunistic feeders near the top of the food chain. Black bears are known to feed in intertidal areas and, therefore, have the potential to contact oil directly by eating sludge washed ashore, grooming oiled hair, eating contaminated intertidal organisms, or scavenging carcasses of mammals and birds killed by oil offshore and deposited on beaches.

A study of the impact of the EVOS on black bear populations was proposed in the 1989 damage assessment plan. That effort proved not feasible, given the logistical difficulties of bear capture in the densely forested habitat of PWS. The literature search proposed for 1990 will provide helpful background information for evaluating the need for a revised detailed population study.

OBJECTIVE

Determine importance of intertidal habitat use by black bear to establish the likelihood of significant impact due to beached oil.

METHODS

Black bear literature will be searched to identify and retrieve any information on the importance of intertidal habitat use. The final product will include a list of citations accompanied by abstracts of each paper and a summary that includes relevant information from all sources.

BUDGET: ADF&G

This study will be a contract for a period March 1, 1990 - February 28, 1991 and will not exceed $10,000.

Contract	$ 10.0
Total	$ 10.0

TERRESTRIAL MAMMAL STUDY NUMBER 3

Study Title: Assessment Of The Effect Of The EVOS On River Otters In PWS

Lead Agency: ADF&G

INTRODUCTION

River otter (Lutra canadensis) populations in PWS rely on intertidal and subtidal environments for food. Studies of similar coastal populations in southeastern Alaska documented that marine fishes, crabs, and other invertebrates dominated food habits (Larson 1983, Woolington 1984). Because critical habitat for this species was heavily contaminated by oil, otter populations are at risk by direct contact with oil or by environmental changes to other habitat components. Data on density prior to the oil spill are lacking, but river otters were probably abundant. The goal of this study is to determine if the EVOS will have measurable effects on these populations. The approach is to 1) examine carcasses to determine direct effects of oil, 2) compare pre- and post-spill river otter dietary information from scats, 3) validate the use of a control area and then, 4) compare population density and various biological aspects between oiled and control study areas.

Necropsy and tissue samples obtained from otter carcasses recovered from oiled beaches will provide information on possible short-term impacts. Magnitude of short-term loses cannot be measured directly because the proportion of recovered carcasses is unknown.

This study will use parallel data collected in a control area (Esther Passage) and an area heavily contaminated by oil (Knight Island) to test for impacts on river otters. Radio telemetry, rates of fecal deposition, food habit analysis, home range determinations, and analyses of habitat selection by otters will provide population characteristics, trends, and indexes for comparing the two areas. Additionally, necropsy and tissue analyses of animals collected outside of the study areas will provide data on presence of hydrocarbons and their long-term effects on individual animals. Results from the study on the effects of hydrocarbons on captive mink (Terrestrial Mammal Study Number 6) will provide the context for interpreting hydrocarbon levels in river otters.

OBJECTIVES

Direct Effects

A_1 - Determine cause of death for river otter recovered from oiled areas via necropsy and histopathological procedures.

A_2 - Test ($\alpha = 0.05$) for higher hydrocarbon levels in river otter in oiled versus unoiled areas.

Population Change

B_1 - Estimate population sizes of river otter within 10% of the true value 95% of the time, on representative oiled and control study areas using mark-recapture methods and test ($\alpha = 0.05$) for lower population levels in oiled versus control areas.

B_2 - Estimate the rate of fecal deposition within 10% of the true value 95% of the time for river otter. This rate will be used as an index to population size to test ($\alpha = 0.05$) for lower rate of deposition in oiled versus control study areas.

B_3 - Test ($\alpha = 0.05$) for lower survivorship of river otter in oiled versus control study areas.

Food Habits

B_4 - Test ($\alpha = 0.05$) for differences in food habits of river otters before and after the oil spill on the oiled study area.

B_5 - Test ($\alpha = 0.05$) for differences in food habits of river otters on oiled and control study areas.

Habitat Use

B_6 - Test ($\alpha = 0.05$) for differences in activity patterns (foraging) of river otters between oiled and control study areas. (limited funding and man power may not allow data collection for this objective)

B_7 - Use home range size and use patterns to test ($\alpha = 0.05$) for differences in habitat selection in river otters between oiled and control study areas.

METHODS

The initial impact assessment concentrated on locating two study areas (control vs. oil impacted) with comparable numbers of active latrine sites for mink and river otters. Each site was given a unique name, plotted on a map and field marked for future relocation, and a site drawing with a rough description made in a field notebook. Sites were cleaned of all scats and then revisited five times between June and September 1989, to obtain data on continued use. After the initial visit the number of scats present were recorded in addition to scat collection for later analyses.

Information obtained during the 1989 initial study for impact response was used in developing the study design for this project. The 59 latrine sites in the control area and 57 sites in the oiled area will be the focus of efforts to live capture otters. Most of these sites will also be utilized to provide scat samples for the study. With qualifications, information obtained on otter densities, habitat selection, and population response to oil will be available for extrapolation to other areas of PWS. Standard operating procedures will be developed for each segment of the long range study to insure data validity.

The following are methods for collecting data by objective.

Direct Effects.

A_1- Necropsy and histopathology will be performed according to standard procedures.

A_2 - Up to 20 additional animals may be collected outside the study area to provide hydrocarbon and histological samples. Necropsy and similar tissue analysis will continue to be made on dead otters found throughout the entire area impacted by the oil.

Population Change

B_1- River otters will be live trapped at latrine sites in the control and oiled study areas. Modified Hancock live traps and drugging boxes to hold otters, as described by Melquist and Hornocker (1979), will be used. Weather permitting, all traps will be monitored daily. All traps will be equipped with a transmitter that signals a sprung trap. Animals will be held only as long as necessary to complete the marking process and provide for their recovery from surgery. Animals will then be released at their original capture site.

Techniques for implantation of radio transmitters will be as described by Woolington (1984). Surgery will be done by a licensed veterinary/biologist or project personnel specifically trained in the technique. Each transmitter is equipped with a "mortality mode" so the fate of individual animals can be determined.

Radioisotope implants in otters will be used to estimate population density in the oiled and control study areas using a mark-recapture method. Marking will be by implantation of radio-labeled, polylactic acid (PLA) tablets to provide a long lasting tracer that can be detected in feces (scats) of river otter (Crabtree et al. 1989). Recoveries of scats from latrine sites will provide the "recaptures" for analysis. This mark-recapture technique has been employed in carnivore studies (Kruuk et al. 1980), including river otters (Knaus et al. 1983, Shirley et al. 1988).

Animals instrumented with VHF transmitters will have radio labeled PLA tablets implanted intra-peritoneally. This method allowed detection for over 10 months in the scats of coyotes (Canis latrans) (Crabtree et al. 1989). A gamma spectrometer will be used to detect and identify radio labeled scats.

Sampling of latrine sites will provide the "recaptures" for simple mark-recapture analysis (Seber 1982). Twenty river otters in each study area will be uniquely marked. A closed population model will be used, employing radio transmitters to determine exactly how many marked animals are resident in the study area while scats are being sampled. Mark-recapture models for closed populations are well established (Dennis et al., In Press; Seber 1982). Latrine sites will be cleared of scats at the start of a sampling period, and visited every one to two days until a predetermined number of scats has been collected.

The distribution of marked animals is likely not to be random, due to the necessity of focussing our capture effort in locations of high animal abundance. Biases can result if the recovery of scats is uneven across low and high density areas within each main study area. A special effort will be made to randomize the recovery of otter scats to ensure every scat is equally likely to be collected.

B_2- Rates of fecal deposition will be used as an index to population size in oiled and control areas. The same latrine sites used for mark-recapture population estimates will be used for estimating fecal deposition rates.

B_3- Estimates of survival will depend on data obtained from otters instrumented with radio transmitters. Data will be obtained coincidental to data gathered for objectives B_1, B_6, and B_7.

Food Habits

B_4 & B_5- Food habits of river otter will be described from prey remains in their feces. Such procedures have been used successfully in past studies (Gilbert and Nancekivell 1982). A preliminary survey of latrine sites conducted in late April and early May 1989, located 59 latrines in the control area and 55 latrines in the oiled area. Feces were collected at each site and resampled four times.

Scats from river otter will be distinguished from those of other mammals by their characteristic morphologies (Murie 1954).

Latrine sites will be resampled when snow free in late spring 1990 in the same manner as those collected following the oil spill. Thereafter, we tentatively plan to collect feces from latrines 1-2 times/week from June through mid-September 1990 on both control and oiled areas.

Laboratory analysis of prey remains in feces of river otter will follow standard procedures (Bowyer et al. 1983).

Because of differential digestibility of prey and variable rates of passage through the gut, volumetric measures of prey remains in mustelid feces are meaningless. Consequently, the analysis will be confined to the occurrence of prey items in latrines and will be expressed in terms of percent of latrines with food items, and percent of total food item (Bowyer et al. 1983). To assure that subsamples from a latrine are representative of that site, all feces from that site will be mixed and a series of subsamples (about the volume of an individual scat) will be drawn and analyzed separately. Sampling will continue until the function between number of prey items and number of samples becomes asymptotic. All latrines included in the analysis, however, will contain at least five scats per sampling period.

Because sample variance is unknown, it is not possible to specify the total number of samples necessary to adequately describe food habits at this time. Reduction in variation of the mean with increasing sample size (of latrines) will be monitored for important food items to ensure that all proportions are estimated within 0.05 of their true value 95% of the time (Kershaw 1964).

Habitat Use

B_6- Activity patterns of radio equipped river otters will be used to test for changes in the availability of prey between oiled and control study areas. A digital recorder linked to a radio receiver will be operated to record activity of otters.

B_7- Data on home range and habitat selection of individuals will be collected daily using radio-locations of telemetered animals. Telemetry will be conducted from a small boat, and the entire coastline of both study areas (oiled and control) will be sampled each day. Because river otter are distributed immediately along coastal areas (Larsen 1983, Johnson 1985), telemetry "fixes" will be made over relatively short distances, and multiple "legs" can be used in triangulation. Consequently, error polygons should be small and biases from animal movements during triangulation will be minimal. Locations determined via telemetry will be confirmed visually whenever possible.

The time at which a telemetry transect starts will be randomized each day to help minimize any bias from duel activities of the mustelids on estimates of home range size and habitat selection. Further, aerial telemetry will be conducted as needed to determine locations of individuals that cannot be located by boat. Telemetry transmitters will be equipped with a mortality signal that will allow the speedy recovery of dead animals.

Methods for analyzing data are detailed below for each objective.

Direct Effects

A_1- A cause of death will be assigned each mink or river otter carcass based upon a necropsy report and lab analysis of tissue specimens. Hydrocarbon levels will be presented for all usable samples.

A_2- A one-tailed Z test for proportions (Snedecor and Cochran, 1980) will be used to test this hypothesis.

Population Change

B_1- Analysis will follow methods described by Dennis et al., (In Press) for sampling a closed population with replacement. Population size and 95% confidence intervals for both control and oil affected areas will be estimated. A one-tailed Z statistic will be used to determine if the population density is lower in the oiled area versus the control area. This test assumes that the population estimates are normally distributed and have equal variance (Seber 1982).

B_2- Differences in rates of scat deposition between oiled and control study areas will be tested ($\alpha = 0.05$) with a single factor covariance analysis model (Neter et al. 1983). The response variable will be rate of scat deposition and the covariate will be the number of latrine sites. Main effects will include oiling and months of study. Since a one-tailed hypothesis is being tested with regard to the oiling main effect, the critical region for this section of the ANOVA table will be one-tailed. If variances are not homogeneous, either a ranked procedure will be employed or the data will be transformed to obtain homogeneous variance or normality.

B_3 - Estimation and analysis of survival distributions for radio marked individuals will follow standard procedures (Pollock et al. 1989). Model assumptions include a random sample of animals, that survival times are independent for different animals, and that censoring mechanisms are random.

Food Habits

B_4 and B_5- Statistical analysis will include only food items that compose at least 10% of the diet. Comparisons of food habits between oiled and control areas and among months will be made with the Quade test including multiple comparisons of food items (Conover 1980).

Habitat Use

B_6- It is hypothesized that if availability of forage fishes in the subtidal zone were reduced due to oil, otters would spend more time foraging to obtain a diet equivalent to that in the control area. Because study areas were selected that contained similarly high populations of otters, it is presumed that both otters and their food were abundant prior to the oil spill. The oil spill may have reduced both river otters and their prey. Consequently, the foraging activities of otters could be expected to change with both their population size and that of their prey.

Although this procedure will allow assessment of a reduction in otters <u>or</u> a reduction in their prey, it will not detect a simultaneous reduction in both.

Differences in activity of river otters (stratified by sex and age class) between oiled and unoiled study areas will be tested (α = 0.05) with a two-tailed Mann-Whitney test (Conover 1980: 216).

B_7- The procedures of Swihart and Slade (1985a,b) will be used to correct for auto correlation among home range locations and to determine the time interval to achieve independence of observations. An adequate number of relocations to assess the seasonal home range of an individual will be determined by obtaining an asymptotic relationship between home range size with increasing number of relocations. Once the proper time interval and sample size have been determined, the method of Dixon and Chapman (1980) will be used to calculate 25%, 50%, 75% and 95% isoclines of home range use.

Isoclines of home range use will be overlaid on detailed maps of coastal habitats. The 95% use isocline will be employed to determine the habitats available for a particular animal. Proportional weighing by 25%, 50% and 75% isoclines within each habitat will determine use. Thus, habitat use and availability will allow a determination of habitat selection for each telemetered individual. Testing for differences in habitat selection (rather than use) between oiled and control areas is essential because a difference in habitat use may occur as a result of differential availability of habitats independent of effects of oiling. A knowledge of habitat selection by river otters is essential for extrapolating from our study areas to effects on habitat oiled in other areas. Consequently, habitat selection will be inferred from a significant difference ($\underline{P}$ < 0.05) in use and availability matrices compared simultaneously with Hotelling's T^2 statistic; _a posteriori_ comparisons of individual habitat types will be accomplished using Bonferroni multiple tests (Johnson and Wichern 1988:188). Similarly, comparisons of habitat selection in oiled and control areas will be made with a multivariate analysis of variance (MANOVA) again using Bonferroni multiple contrasts.

BIBLIOGRAPHY

Adorjan, A.S. and G.B. Kolenosky. 1969. A manual for the identification of hairs of selected Ontario mammals. Ontario Dept. Lands and Forests, Res. Rep. (Wildlife) No. 90, 64pp.

Bowyer, R.T. and K.D. Curry. 1983. Use of a roller press to obtain cuticular impressions of guard hairs on acetate strips. J. Mammal. 64:531-532.

Bowyer, R.T., S.A. McKenna, and M.E. Shea. 1983. Seasonal changes in Coyote food habits as determined by fecal analysis. Amer. Midland Nat. 109:266-273.

Bunham, K. P. and W. S. Overton. 1978. Estimation of the size of a closed population when capture probabilities vary among animals. Biometrika 65:625-633.

Chao, A. 1989. Estimating population size for sparse data in capture-recapture experiments. Biometrics 45(2):427-438.

Conover, W.J. 1980. Practical nonparametric statistics. John Wiley & Sons, New York, 493pp.

Crabtree, R.L., F.G. Burton, T.R. Garland, D.A. Cataldo, and W.H. Rickard. 1989. Slow-release radioisotope implants as individual markers for carnivores. J. Wildl. Manage. 53: 949-955.

Davis, D.E. and R.L. Winstead. 1980. Estimating the numbers of wildlife populations. Pp. 221-245 in S.D. Schemnitz, ed. Wildlife Management Techniques Manual. Fourth Ed. The Wildl. Soc., Washington, DC.

Day, M. G. 1966. Identification of hair and feather remains in the gut and feces of stoats and weasels. J. Zool. (Lond.) 148:201-217.

Dennis, B., R.L. Crabtree, and E.V. Eartan. In Press.

Statistical methods for closed population estimation using radioisotope tagging. J.Widl. Manage.

Dixon, K.R. and J.A. Chapman. 1980. Harmonic mean measure of animal activity. Ecology 61:1040-1044.

Fleiss, J.L. 1973. Statistical methods for rates and proportions. John Wiley & Sons, New York, 223pp.

Gilbert, F.F. and E.G. Nancekivell. 1982. Food habits of mink (Mustela vision) and otter (Lutra canadensis) in northeastern Alberta. Can. J. Zool. 60:1282-1288.

Hall, R.E. and K.R. Kelson. 1959. Mammals of North America. Ronald Press, New York, 1983pp.

Johnson, R.A. and D.W. Wichern. 1988. Applied multivariate statistical analysis. Prentice Hall, New Jersey, 606pp.

Kershaw, K.K. 1964. Quantitative and dynamic ecology. Edward Arnold, London, 1983pp.

Knaus, R.M., N. Kinler, and R.G. Linscombe. 1983. Estimating river otter populations: the feasibility of ^{65}Zn to label feces. Wildl Soc. Bull. 11:375-377.

Kruuk, H., M. Gorman, and T. Parrish. 1980. The use of ^{65}Zn for estimating populations of carnivores. Oikos 34:206-208.

Larsen, D.N. 1983. Habitats, movements, and foods of river otters in coastal southeastern Alaska. Unpubl. M.S. Thesis, Univ. of Alaska Fairbanks, 149pp.

Mayer, W.V. 1952. The hair of California mammals with keys to the dorsal guard hairs of California mammals. Amer. Midland Nat. 48:480-512.

Melquist, W.E. and M.G. Hornocker. 1979. Methods and techniques for studying and censusing river otter populations. Tech Report 78, Forest, Wildl. and Range Exper. Station, University of Idaho, Moscow, Idaho, 17pp.

Morrow, J.E. 1979. Preliminary keys to otoliths of some adult fishes of the Gulf of Alaska, Bering Sea, and Beaufort Sea. NOAH Tech. Report NMFS Circ. No. 420

Murie, O.J. 1954. A field guide to animal tracks. Houghton Mifflin, Boston, 374pp.

Neter, J., W. Wasserman, and M.H. Kutner. 1983. Applied linear statistical methods. Richard D. Irwin, Homewood, Illinois, 1127pp.

Pollock, K.H., S.R. Winterstein and M.J. Conroy. 1989. Estimation and analysis of survival distributions for radio-tagged animals. Biometrics 45:99-109.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Macmillan, New York.

Shirley, M.G., R.G. Linscombe, N.W. Kinler, R.M. Knaus, and V.L Wright. 1988. Population estimates of river otters in a Louisiana coastal marshland. J. Wild. Manage. 52: 512-515.

Snedecor, G. W.1 and W. G. Cochran. 1980. Statistical methods, 7th ed. Iowa State University Press, Ames Iowa 507pp.

Swihart, R.K. and N.A. Slade. 1985a. Testing for independence of observations in animal movements. Ecology 66:1176-1184.

Swihart, R.K. and N.A. Slade. 1985b. Influence of sampling interval on estimates of home range size. J. Wildl. Manage. 49:1019-1025.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos Natl. Lab. Publ. LA-8787-NERP. 235pp.

Woolington, J.D. 1984. Habitat use and movements of river otters at Kelp Bay, Baranof Island, Alaska. Unpubl. M.S. Thesis, Univ. of Alaska Fairbanks, 47pp.

BUDGET: ADF&G

Personnel	$	125.4
Travel & per diem		20.0
Contract		166.7
Commodities		35.5
Total	$	347.6

TERRESTRIAL MAMMAL STUDY NUMBER 4

Study Title: Assessment of the EVOS on Brown Bear Populations on the Alaska Peninsula

Lead Agency: ADF&G

Cooperating Agencies: DOI, NPS, FWS

INTRODUCTION

Relatively high densities of brown bears (Ursus arctos) occur along the 120-mile section of shoreline on the southern edge of the Alaska Peninsula that was impacted by crude oil from the EVOS. There has been no objective estimate of the number of bears in the affected areas, but it is suspected that densities along the oil-contaminated Katmai coast are higher than those reported from other coastal brown bear populations: 1 bear/1.1 mi^2 near Terror Lake on northern Kodiak Island (Barnes et al. 1988) and 1 bear/2.0 mi^2 near Black Lake on the southern Alaska Peninsula (Miller and Sellers 1989). These bears are an important economic and aesthetic resource. On the Alaska Peninsula, Alaska residents and guided non-residents harvest about 250 bears annually, spending an estimated $2.2 million on those hunts (ADF&G files). Thousands of visitors from around the world come to Katmai National Park and the McNeil River State Game Sanctuary to observe and photograph bears.

Brown bears are omnivorous, opportunistic feeders near the top of the food chain. They may ingest oil directly by eating mousse and tar balls washed ashore, by eating oiled plants and clams, by scavenging oiled carcasses of animals killed offshore and deposited on beaches, or by grooming oiled fur. Bears may also consume animals that have been physiologically contaminated by sublethal doses of oil. Effects of oil ingestion on individuals could range from quick death from acute toxic effects to long-term suppression of reproduction. Experimental work with oiled polar bears in Canada (Oritsland, et al. 1981) indicated that two of three animals died from organ failure after grooming. Effects of oil contamination on bear populations could range from sharp, immediate declines to subtle long-term reductions as chronic effects from hydrocarbons stored in fat are expressed.

To continue the determination of impact of EVOS on individual brown bears and the coastal Alaska peninsula brown bear population, a study area along the coast of Katmai National Park was selected. This project will capture and radio-collar an additional sample of bears in oiled areas and will compare the natural mortality rate of this sample with that of coastal populations on Kodiak Island and near Black Lake further south on the Alaska Peninsula which were not exposed to large amounts of crude oil. Dead bears found incidentally and radio-collared bears that die will be necropsied, tissue samples taken, and the cause of death determined. Extent of oil ingestion and the physiological effects will also be examined.

OBJECTIVES

A. Test the hypothesis that radio-collared brown bears in an oil-contaminated area of the Alaska Peninsula (Katmai coast) ingested hydrocarbons (as evidenced by the level of hydrocarbons in fecal samples) at higher concentrations than radio-collared bears in an area on the Peninsula that was not contaminated (Black Lake).

B. Test the hypothesis that natural mortality rates of female brown bears near oiled areas of the Katmai coast occurred at a higher rate than females in other coastal brown bear populations inhabiting non-oiled areas during a period of three years after EVOS.

C. Test the hypothesis that some of the mortality of brown bears near the Katmai coast can be attributed to the physiological effects of ingesting hydrocarbons.

D. Estimate the adult brown bear population density of the study area (approximately 150 square miles) through a cooperative project with the NPS using a modified capture-recapture technique (Miller et al. 1987) with the goal of obtaining a coefficient of variation of 0.10.

METHODS

Bears will be captured in the spring of 1990 by using a fixed-wing spotter aircraft to locate bears and direct a helicopter with an immobilizing team to the site. Each bear will be measured (skull length and width), weighed, tattooed (lips and groin), and fitted with ear tags and a radio-transmitter with mortality sensor.

Blood and fecal samples will be collected from bears captured along the Katmai coast and near Black Lake during the spring. Whole blood will be collected in heparinized and non-heparinized collecting tubes. Packed cell volume and percent hemoglobin in the blood will be determined in accordance with standard operating procedures and serum will be frozen and sent into an approved laboratory for analysis.

During 1990, radio-collared bears will be relocated by a fixed-winged aircraft at scheduled two-three day intervals until over 75% of the radio-collared bears are in winter dens. One flight per month will be scheduled during the denning period. Radio-tracking flights should continue for two years. During 1991, flights will be made at two week intervals while bears are active and monthly during denning. A sample of at least 30 radio-collared bears will be followed into dens each year. It is anticipated that at least 40 bears must have functioning radio-collars in the spring to achieve a sample of 30 in the fall. To maintain this sample size, collaring operations will be necessary during the spring of 1990 and possibly in 1991.

Mortality data will be collected during radio-tracking flights. When a dead bear is observed in the study area, gross necropsies will be performed in the field. Data on sex, age, and probable cause and time of death will be recorded. Tissue samples from recent mortalities will be collected for histopathological and hydrocarbon analysis. Annual survival, distributions, and mortality rates will be calculated using modified Kaplan-Meier techniques (Pollock et al. 1989). Results will be compared with mortality rates from the Black Lake and Terror Lake (Kodiak) study areas.

The density estimate (Miller et al. 1987) will be conducted in the spring of 1990. Prior to the recapture portion of the procedure, a representative sample of 50 radio-collared bears will be required to serve as marks for the estimator. Collars will be distributed proportionally to the estimated proportion of bears in various reproductive categories (e.g. lone adult males, lone adult females, subadult males, subadult females, females with cubs-of-the-year, females with yearling or older offspring) in the population. Only independent observations of individuals will be used in the estimator.

Data obtained from the density estimate and mortality rate calculations will be used to estimate the total number of bears that were killed by the effects of EVOS by comparison between years and between the oiled area and the control area. A subsequent population estimate, using the same methods in the same oil-contaminated area, will be derived in the spring of 1992. It has been reported that capture-recapture techniques, such as the proposed density estimate procedure, tend to underestimate the known size of big game populations (deer) by 10-20% in most instances; but, the estimators can be used to detect population trends by comparing estimates over time from the same area (Becker 1989). Due to suspected heterogeneity among bear classes and lower sightability of bears, compared to deer, we suspect that the true number of bears in the population will be underestimated by an unknown amount somewhat greater than the 10-20% reported in the literature.

Throughout all phases of this study we will attempt to identify potential alternative methods and strategies for restoration of lost use, populations, or habitat if injury is identified. The final report will include a listing of suggested ways to address long-term restoration projects.

A two sample, one-sided T-statistic (Snedecor & Cochran, 1980) will be used to test the oil ingestion hypothesis (Objective A). This statistic assumes the means are normally distributed. If necessary, transformations will be used to ensure that the normality assumption is met.

The natural mortality rate hypothesis (Objective B) will be tested using a log-rank test to compare the two Kaplan-Meier survival functions (Pollack et al. 1989). This statistic assumes that differences in survival functions are the result of a constant shift parameter (Cox & Oakes 1988). This assumption will be examined by cumulative hazard plots of the two distributions and possibly involve analysis with time dependent covariates (Cox & Oakes 1988). It is assumed that bear populations near Black Lake and Terror Lake are more likely to be shot by hunters, so all hunter-killed radio collared bears will be censored (as outlined in Pollock et al. (1989) for animals that emigrated from a study area or were otherwise lost).

Tissues will be collected and analyzed as outlined by the EVOS Histopathological Technical Group and the Hydrocarbon Technical Group to test the hydrocarbon mortality hypothesis (Objective C). All statistical analyses will be performed at an alpha level of 0.05. A sample size will be used that is adequate to detect at least one bear affected by oil contamination with a given percentage of certainty, for varying proportions of the population contaminated by hydrocarbons. These sample size calculations are based on a binomial distribution (Mendenhall, Schaffer and Wackerly 1981) and assume that the sample size is very small compared to the population total. For the purposes of this study it will be assumed that at least 10% of the bear population was affected by EVOS; therefore, a total sample size of at least 29 bears will have to be followed by radio-telemetry to be 95% certain of following at least one bear affected by hydrocarbons.

The Lincoln-Peterson estimator (Overton 1971) will be used to estimate daily adult population levels (Objective D). The mean of the estimates and its standard error will be used as the point estimate and standard deviation. The assumptions of this estimator are (White et al. 1982):

1) all radio-collars are retained;
2) all animals are correctly classified as marked or unmarked;
3) the recaptures (sightings) of adult bears are independent;
4) the population is geographically and demographically closed;
5) all bears have equal capture probabilities that are constant over time.

The geographic closure assumption will be met by determining the number of radio-collared bears in the study area on a daily basis, and assuming that the proportion of marked bears in the area is representative of the unmarked bears. Assumption #5 can be relaxed to: average probability of capturing a marked animal equals the average probability of capturing an unmarked animal (Overton 1971). If capture heterogeneity exists, which it probably does with brown bears, then mark and recapture estimates tend to be biased low, because the animals that are easier to catch are over represented in the marked sample. Because of this, calculated confidence intervals will not retain their statistical validity, and as a result, the precision goal was stated in terms of the coefficient of variation.

BIBLIOGRAPHY

Barnes, V.G. Jr., R.B. Smith, and L.J. Van Daele. 1988. Density estimates and estimated population of brown bears on Kodiak and adjacent islands, 1987. Unpublished report to the Kodiak Brown Bear Research and Habitat Maintenance Trust. Anchorage, AK. 34pp.

Becker, E.F. 1989. Mark recapture estimates versus known populations. Memo to ADF&G bear researchers, dated Aug. 11, 1989. 13pp.

Cox, D. R. and D. Oakes. 1988. Analysis of statistical data. Chapman and Hall. London. 201 pp.

Mendenhall, W., R.L. Schaffer, and D.D. Wackerly. 1981. Mathematical Statistics with Applications. Duxbury Press. Boston, Mass. 686 pp.

Miller, S.D., E.F. Becker, and W.B. Ballard. 1987. Black and brown bear density estimates using modified capture-recapture techniques in Alaska. Int. Conf. Bear Res. and Manage. 7:23-35.

Miller, S.D. and R.A. Sellers. 1989. Brown bear density on the Alaska Peninsula at Black Lake, Alaska. Unpublished preliminary report for the National Park Service, U.S. Fish and Wildlife Service, and the Alaska Department of Fish and Game. Anchorage, AK. 36 pp.

Oritsland, N.A., F.R. Engelhardt, F.A. Juck, R.J. Hurst, and P.D. Watts. 1981. Effect of Crude Oil on Polar Bears. Can. Dept. Indian Affairs & North Devel. Publ. No. QS-8283-020-EE-A1.

Overton, W. S. 1971. Estimating the number of animals in wildlife populations IN wildlife management techniques.

R. H. Giles ed. The Wildl. Soc. Washington, D. C. Pp. 403-456.

Pollock, K.H., S.R. Winterstein, C.M. Bunck, and P.D. Curtis. 1989. Survival analysis in telemetry studies: The staggered entry design. J. Wildl. Manage. 53(1):7-15.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical Methods; Seventh Edition. Iowa St. Univ. Press. Ames, Iowa. 507 pp.

White, G. C., D. R. Anderson, A. P. Burnham, and D. L. Otis. 1982. Capture-Recapture and Removal Methods for Sampling Closed Populations. Los Alamos Natl. Lab. Publ. LA-8787-NERP. 235 pp.

BUDGET: ADF&G

Salaries	$	44.6
Travel		4.3
Services		47.0
Commodities		9.8
Equipment		20.0
Total	$	125.7

TERRESTRIAL MAMMAL STUDY NUMBER 6

Study Title: Influence of Oil Hydrocarbons on Reproduction of Mink (Mustela vision)

Lead Agency: ADF&G

INTRODUCTION

The mink is a carnivorous mammal inhabiting the margins of streams, lakes, marshes, and marine islands throughout most of North America. It is at the top of the food chain and thus exposed to a wide variety of environmental contaminants. Certainly the most dramatic effect of a toxicant or pollutant is outright death of the animal. An equally devastating effect on the animal population, however, is for apparently healthy animals to fail to reproduce or to produce weakened offspring. Studies with ranched mink have documented that these animals are sensitive to many chemical and biological compounds (Sundqvist et al.1989). Some of those known to interfere with reproduction include heavy metals, halogenated hydrocarbon pesticides and other aromatic, halogenated hydrocarbons (Ringer, 1981; Sundqvist et al.1989). In the mid-1960s a decline in reproductive performance in ranched mink (Hartsough, 1965) was eventually traced to high polychlorinated biphenyl (PCB) content of Great Lakes fish used in commercial mink diets (Aulerich et al.1971; Aulerich et al.1973). Ranched mink fed 2-5 ppm PCBs, 1-2.5 ppm polybrominated biphenyls, or 5-25 ppm hexachlorobenzene suffered complete reproductive failure, significantly reduced litter size and/or excessive kit mortality (Aulerich et al.1985; Aulerich, and Ringer, 1979; Aulerich, and Ringer, 1977; Bleavins et al.1984; Bleavins et al.1980; Hornshaw et al.1983; Ringer, 1981; Ringer et al.1972; Rush et al.1983; Wren et al.1987). Particularly dangerous are compounds like PCBs that accumulate in the subcutaneous fat (Hornshaw et al.1983). Therefore, it is possible that hydrocarbons in crude oil ingested by mink and other carnivores may interfere with reproduction.

Crude oil released into the environment is immediately subjected to a variety of weathering processes (Payne and McNabb, 1984). Within a few weeks of an oil spill the majority of the more toxic, lower molecular weight compounds are eliminated, primarily through evaporation (Payne and McNabb, 1984). However, heavier distillate products not subject to significant evaporative loss persist in the environment and are more likely to enter the food chain in significant quantities. It is the effect of ingestion of this weathered oil that will be studied.

Mink feed on fish, small mammals, frogs, aquatic insects, and occasionally birds. These prey species live in areas impacted by the EVOS. Therefore, it is highly probable that mink will be exposed to oil hydrocarbons. But direct cause and effect relationships such as the influence of oil hydrocarbons on reproduction are difficult to demonstrate in a field study. The complexity of a natural setting imposes too many uncontrolled variables. Even if field studies measure hydrocarbons from wild animals or show a change in the population dynamics of one or more species, there will always be the unanswered question: Was it the oil or some other unmeasured factor that influenced reproductive performance? A controlled experiment in the laboratory will be conducted to define the effects of short-term and long-term ingestion of non-lethal amounts of weathered Prudhoe Bay crude oil (WPBC) using ranched mink as a model species. Mink will be used for three reasons: 1) mink are known to be sensitive to hydrocarbon pollutants, 2) mink inhabit the PWS area and are thus at risk for exposure to oil hydrocarbons in feed, and 3) the mink is a well-established model for laboratory research and thus there is excellent documentation of their reproductive physiology (Enders 1952; Sundqvist, et al., 1989). Ranched mink are not domestic animals, and their physiological response to oil ingestion in the laboratory setting can be predicted to be no different from that of their wild counterparts.

OBJECTIVES

A. Short-Term Ingestion of Weathered Prudhoe Bay Crude Oil

Test the hypothesis that short-term (seven day), low-level (100 ppm) ingestion of WPBC oil during pre-estrus, diapause, gestation, or lactation does not produce a significant ($P < 0.05$) difference in the reproduction of female mink. Reproductive variables will be the number of kits per litter, kit survival, kit growth and maturation, and histology of adult and kit reproductive tracts.

B. Long-Term Ingestion of Weathered Prudhoe Bay Crude Oil

Test the hypothesis that continual, low-level (100 ppm) ingestion of WPBC oil starting during pre-estrus and continuing through to the weaning of kits does not produce a significant ($P < 0.05$) difference in reproduction of female mink. Reproductive variables will be the number of kits per litter, kit survival, kit growth and maturation, and histology of adult and kit reproductive tracts.

METHODS

Crude oil from the Exxon Valdez will be weathered by placing it in a flat bottomed, solvent-rinsed vessel to a depth no greater than 2 cm. The oil will be gently agitated in a fume hood for seven days at room temperature.

All mink will be fed commercial mink ration consisting of ground fish, chicken and beef by-products. WPBC oil will be mixed into the feed at a rate of 100 ppm. In order to measure such small amounts accurately, we will first dilute the WPBC in salmon oil. The resulting oiled diet will contain 100 ppm WPBC and 10 ml salmon oil per kg commercial mink ration. The level of 100 ppm WPBC oil was chosen because it did not alter food palatability and the oiled food was readily consumed by the mink. In addition, this level of contamination does not cause the mink to suffer or exhibit any clinical symptoms.

For the short-term study, mink will be fed either 0 WPBC (control group) or 100 ppm WPBC for seven days at a time specific to the reproductive cycle (pre-estrus, diapause, pregnancy, and lactation). A total of 70 female mink will be used. Mink (20 each) will be randomly assigned to the control and pre-estrus groups prior to the breeding season. Successfully mated mink from the remaining 20 animals will be randomly assigned to the diapause, pregnancy, and lactation groups following breeding. The female mink will be bred to untreated males. Males will be checked for fertility by palpation of testes, demonstration of copulatory behavior, and evidence of motile sperm in vaginal smears following mating. Females will be allowed to rear their young to weaning age. After weaning, adults and selected kits will be euthanized and tissue and blood samples will be collected for histopathology, hydrocarbon analyses and liver cytochrome P450 analyses. Estrous behavior will be analyzed by comparing the number of females successfully bred and the time of breeding of the 20 control animals to the 20 pre-estrus animals. For these tests all 20 animals in each group will be included. For all other tests, only those animals successfully bred will be included. The response variables to be analyzed on mated females in each group include number of kits born, number of live kits born, birth weight of kits, survival rate of kits, and growth rate of kits.

For the long-term study twenty female mink will be fed 100 ppm WPBC oil in their diets beginning in February, 1990 and continuing until kits are weaned in June, 1990. The control group (n=20) from the short-term study will also serve as a control for this study. All mink in this long-term exposure study will be bred to untreated males and will be allowed to rear their young to weaning age. Adults and selected kits will be euthanized at weaning, and tissue and blood samples will be collected for histopathology, hydrocarbon analyses and liver cytochrome P450 analyses. The response variables to be examined in this study are identical to those in the short-term exposure study: mating activity, number of kits born, number of live kits born, birth weight of kits, survival, growth and maturation of kits.

The University of Alaska Fairbanks, (UAF), who will conduct this research, has on file with the Office for Protection Against Research Risks, National Institutes of Health, an "Assurance of Compliance with Public Health Service Policy on Humane Care and Use of Laboratory Animals". The University's Animal Facilities are licensed by the United States Department of Agriculture and are subject to twice yearly, unannounced inspections by USDA veterinarians to ensure compliance with the Animal Welfare Act.

UAF has a full-time, staff veterinarian who supervises the veterinary care program as outlined in the Regulations of the Animal Welfare Act. The University also has an Institutional Animal Care and Use Committee mandated by Public Health Service Policy and the Animal Welfare Act. This project was reviewed and approved, without modification, by the committee.

Because of the nature of the response variables being examined, a number of different statistical tests will be used. Comparisons between two groups involving binomial variables, such as number of females bred, will be tested by chi-square. Analysis of variables involving kits as an experimental unit will be tested by analysis of variance. When there are significant differences, treatment groups will be compared to the control group by Dunnet's test. Because kit birth weight and kit growth rate are expected to vary with litter size unrelated to specific treatment effects, analysis of covariance with litter size as the covariate will be done. Statistical significance of differences between variables involving the long-term exposure group and the control animals will be determined by T-test or by chi-square as appropriate.

BIBLIOGRAPHY

Aulerich, R.J., Bursian, S.J., Breslian, W.J., Olson, B.A., and Ringer, R.K. (1985). Toxicological manifestations of 2,4,5,2',4',5'-2,3,6,2',3',6'and 3,4,5,3',4',5'-hexachlorobiphenyl and aroclor 1254 in mink. J.Toxicol.Environ.Health **15**, 63-79.

Aulerich, R.J. and Ringer, R.K. (1977). Current status of PCB toxicity to mink, and effect on their reproduction. Archs environmental Contamination Toxic. **6**, 279-292.

Aulerich, R.J. and Ringer, R.K. (1979). Toxic effects of dietary polybrominated biphenyls on mink. Archs environmental Contamination Toxic. **8**, 487-489.

Aulerich, R.J., Ringer, R.K., and Iwamoto, S. (1973). Reproductive failure and mortality in mink fed on Great Lakes fish. J.Reprod.Fert. **Suppl.19**, 365-376.

Aulerich, R.J., Ringer, R.K., Seagran, H.L., and Youatt, W.G. (1971). Effects of feeding coho salmon and other Great Lake fish on mink reproduction. Can.J.Zool. **49**, 611-616.

Bleavins, M.R., Aulerich, R.J., and Ringer, R.K. (1980). Polychlorinated biphenyls (Aroclors 1016 and 1242): effects on survival and reproduction in ferrets. Archs environmental Contamination Toxic. **9**, 627-635.

Bleavins, M.R., Aulerich, R.J., and Ringer, R.K. (1984). Effects of chronic dietary hexachlorobenzene exposure on the reproductive performance and survivability of mink and European ferrets. Archs environmental Contamination Toxic. **13**, 357-365.

Enders, R.K. (1952). Reproduction in the mink. Proc.Am.Phil.Soc. **96**, 691-755.

Hartsough, G.R. (1965). Great Lakes fish now suspect as mink food. Am.Fur Breeder **38**, 25-27.

Hornshaw, T.C. Aulerich, R.J., and Johnson, H.E. (1983). Feeding Great Lakes fish to mink: effect on mink and accumulation and elimination of PCB's by mink. J.Toxicol.Environ.Health **11**, 933-946.

Payne, J.R. and McNabb, G.D.JR. (1984). Weathering of petroleum in the marine environment. MTS Journal **18(3)**, 1-20.

Ringer, R.K. (1981). The effects of environmental contaminants on reproduction in the mink (Mustela vison). In:" Environmental factors in mammal reproduction" (Gilmore, D., and Cook, B., Eds.) pp. 232-237. University Park Press, Baltimore.

Ringer, R.K., Aulerich, R.J., and Zabik, M. (1972). Effect of dietary polychlorinated biphenyls on growth and reproduction in the mink. Am.Chem.Soc.Nat.Meeting **12**, 149-152.

Rush, G.F., Smith, J.H., Maita, K., et al (1983). Perinatal hexachlorobenzene toxicity in the mink. Environ. Res. **31**, 116-124.

Sundqvist, C., Amador, A.G., and Bartke, A. (1989). Reproduction and fertility in the mink (Mustela vison). J.Reprod.Fertil. **85**, 413-441.

Wren, C.D., Hunter, D.B., Leatherland, J.F., and Stokes, P.M. (1987). The effects of polychlorinated biphenyls and methylmercury, singly and in combination on mink. II: Reproduction and kit development. Archs environmental Contamination Toxic. **16**, 449-454.

BUDGET: ADF&G

Salaries	$	23.7
Travel		0.0
Contracts		62.3
Supplies		48.0
Equipment		0.0
Total	$	134.0

BIRD INJURY ASSESSMENT

The EVOS resulted in the death of a large number of migratory birds, especially seabirds, waterfowl, and bald eagles. In the months following the spill it became apparent that the vast populations of numerous bird species that inhabit or utilize the spill zone remained at risk to direct mortality as well as sublethal, long-term damages.

Fourteen studies were developed and deployed during 1989 to document damages to migratory birds. It was recognized early in the process that it was not possible to study all the bird species potentially affected by the oil spill nor the full scope of effects to any species. Therefore, efforts were concentrated on studying key species or groups of species where injury was most evident and valid damage assessment could be determined in a reasonably cost-effective manner.

Seven of these studies will be continued in 1990. Some studies were not continued because it was concluded that all data pertinent to assessing damages likely to be gathered had indeed been gathered. Some studies, such as Bird Studies B6, B8 and B9 were either integrated into the remaining studies or are being conducted independent of the NRDA process.

Continuing studies have been expanded and/or modified in response to comments from reviewers and the public. The beached bird survey, for example, was carefully designed to provide essential data on bird drift and sinking rates that will increase the accuracy of total bird mortality estimates. Both the eagle and peregrine falcon studies will provide information on loss to breeding populations, as well as reproductive success. The seabird colony and seabird and waterfowl surveys will provide a means to compare pre and post spill populations. Finally, the sea duck study will provide important information on sublethal effects of the spill on harlequin ducks.

BIRD STUDY NUMBER 1

Study Title: An Assessment of Damage to Seabirds in PWS and the western GOA Resulting from the EVOS.

Lead Agency: FWS

INTRODUCTION

This study will assess mortality of marine birds following the EVOS by adapting existing bird damage assessment models to estimate total seabird mortality. The proposed field studies will examine the general characteristics of the decomposition and disappearance of bird carcasses under environmental conditions typical of PWS and the GOA to determine the rate at which carcasses are lost and the factors affecting that rate. It is not possible to simulate the exact environmental conditions prevailing during the spill, in particular the wind and current conditions and the presence of large floating mats of oil.

OBJECTIVES

A. Synthesize available information on the beachcast-bird recovery effort.

B. Determine the number of birds that died as a consequence of oiling.

C. Determine the rate of carcass loss at sea and the time-course of sinking, decomposition and scavenging.

D. Develop an estimate of total seabird mortality.

METHODS

The modeling approach is based on risk assessment models developed for the Pribilof Islands, Kodiak Island, and the Southern California Bight, and on damage assessment models developed for the T/V Puerto Rican and T/V Apex Houston oil spills (Ford et al. 1982, Weins et al. 1982, Ford 1984, Dobbin et al. 1986, Ford et al. 1987, Page et al. 1990).

The carcasses of oiled seabirds may be assumed to have encountered one of three fates:

(1) beached but not recovered,

(2) lost at sea without making landfall,

(3) beached and recovered.

The general approach will be to utilize data for birds which were beached and were recovered to estimate the total number of birds which were beached, and, with the aid of oil spill trajectory information, to work backwards from the beaches where birds were recovered in order to estimate the total number of birds which were directed toward the beach but were lost at sea before being beached.

Unless a beach is thoroughly searched at frequent intervals, some of the beached birds will not be recovered. During the Apex Houston oil spill in California, Page and Carter (1986) found that only 60% of the carcasses persisted on the beach face from one day to the next. Beached birds may not be recovered due to the scavenging, burial, or reflotation of carcasses. A model to estimate the actual number of carcasses deposited on a beach based on the observed number of carcasses on the beach is presented at Page et al. 1986. Data sufficient for this type of modeling are:

(1) The arrival rate of carcasses on a given beach as a function of time.

(2) The frequency with which the beach was searched.

(3) The likelihood that a carcass will not be detectable as a function of the length of time spent on the beach and the age of the carcass when it is first cast.

Some of the data types listed above will need to be derived from information collected during the spill, and others will be estimated as a part of the proposed field studies. The arrival of bird carcasses on a given beach typically peaks rapidly, and tapers off over a period of up to a week. A typical arrival curve can usually be constructed from more frequently searched beaches and applied to less frequently searched beaches. Data on the disappearance rates of beached carcasses and the distance moved by a refloated carcass would be collected as a part of the proposed study.

In addition to carcasses that were not recovered on searched beaches, many carcasses were probably deposited on beaches which were not searched at all. This effect will be accounted for by identifying a number of beached bird recovery areas based on coastal location and geomorphology. Within a recovery area, it is assumed that the average lineal density of carcasses for a given beach type in the unsampled area was the same as that in the sampled area within each sector. Using a Geographical Information System, the lineal extent of searched and unsearched beaches within each sector will be determined from a digital coastline.

Even after correcting the estimate of beached birds for birds that were beached but were not recovered, a large fraction of the mortality will remain unmeasured. Carcasses that are drifting landward may not beach because they sink or are scavenged along the way. The process of carcass loss both at sea and on the beach face is poorly understood, but is critical to the estimate of total mortality since this appears to have been the fate of a large proportion of the birds killed in other spills. The component of the at-sea loss from sinking, scavenging, or other causes will be computed by taking the number of birds (corrected for recovery on the beach), estimating the time spent at sea, and correcting for the loss in transit. Time spent at sea will be estimated using trajectory data. These sources will be used to determine the likely path followed by a drifting seabird carcass to reach a given beach. The distribution of time spent at sea for carcasses found on that beach will be estimated by integrating the likely path of the oil reaching that beach with a density surface describing the at-sea distribution of birds through which the trajectory passed. The at-sea distribution will be estimated using historical data. Distributional data of this type for the GOA and PWS is known to have a high degree of variability both because of sample size and inter-annual variation. The large scale aspects of bird distributions, however, such as the relationship of concentrations of birds relative to the shelf break or to colony sites can be expected to be conservative and can be adequately described by existing data. As part of the sensitivity analysis, the effect of alternative at-sea distributions of birds on model results will be tested. Ongoing studies suggest that the loss of carcasses at sea increases with time. The process of entering the near shore environment or beaching probably accelerates the disappearance rate, especially for older carcasses.

Some carcasses will also be carried out to sea by winds and currents. The size of this component of the at-sea loss will be estimated using trajectory and bird distribution data.

The effect of changing the value of a single input parameter on model results will be examined for all single-valued parameters for which the exact value is arguable. This will be done by running the model with a series of different values for a given parameter and plotting the estimated number of birds killed as a function of the input value for that parameter. Examples of the kind of parameters which could be analyzed in this way include the disappearance rate of carcasses on the beach face, the proportion of birds at risk which actually died, etc.

The effect of simultaneously using best-case and worst-case values for all appropriate parameters will be examined in order to generate maximum and minimum estimates of total mortality. The effect of varying some of the inputs which are not single valued, such as the distribution of birds at sea based on historical data, will also be examined. This would be done by manually constructing alternative distributions which are consistent with the biology of various species, but which would lead to either increased or decreased values of total mortality.

An alternative is to use a Monte Carlo type approach based on the use of probability density functions for arguable parameters (Ford et al. 1982).

Detailed information describing recovery efforts will be used to correct the model input values for variation in level of effort. To the extent necessary, a general description of the recovery effort will be pieced together from records accompanying the frozen specimens. These records indicate where the particular birds were recovered and when.

Logbooks will be reviewed to determine the distribution of search effort along the coastline impacted by EVOS, although in some cases it may be necessary to estimate search effort from other sources including interviews and returns of beachcast birds.

Dead birds collected following the spill are presently bagged and stored in freezers in Anchorage. Seabirds die for a variety of reasons and may have been oiled secondarily. A sample (approximately 10%) of recovered birds will be examined to quantify the proportion of unoiled birds that may have been recovered in different areas and times after the spill, and to describe the degree of oiling and state of decomposition for a number of birds from several locations. Some necropsy work may be performed on unoiled or lightly-oiled birds to determine whether oil had been ingested.

Field studies will be conducted to determine an estimate of loss rate of oiled birds at sea. The loss of birds increases over time, and, ultimately, would reach 100% for birds not beached. The loss rate of birds oiled at sea can be estimated by radio-tracking of free-drifting carcasses. The study will be conducted in two phases, the first focusing on PWS and the second on the Alaska Peninsula where much of the impact on seabird communities occurred.

Free-drifting carcasses will be radio-tracked to obtain data on the rate of loss of oiled carcasses following release. The proportion of the sample group that is deposited on land will be determined. Carcasses will be released from known locations along different stretches of coastline. Over the duration of the study, the position of a carcass will be monitored until it has become beachcast or the signal is lost. Since the failure rate of the radio-tags is very low, loss of signal indicates that a carcass has become submerged (taking the radio with it) or has drifted out of range. In order to distinguish between these two possibilities, a set of "decoys" will be released as a control. In theory, carcasses and decoys will drift in the same manner but one group will begin to sink (the carcasses) and the other will not. By comparison of data from the two groups, the loss rate of carcasses over time can be calculated. To the limits of data, we will correlate rate of loss with species, degree of decomposition, and degree of oiling.

Some beached carcasses will be inspected by the boat crew for locations that can be safely visited. Beached carcasses and decoys will be photographed and scored for visibility and other factors that would affect their collection during beach clean-up effort and will be left in place and monitored from the air to determine if they are refloated.

Each carcass and decoy will be equipped with a radio-tag that floats upright. Each radio unit weighing approximately 15 grams, has an effective range of about 03 nmi at 2000 feet above sea level (ASL) flight altitude, with a battery life of 50 days. The transmitters are placed in devices that are completely self-righting and have neutral buoyancy. Radio-tags are activated by removal of an external magnet. Each radio-tag has a characteristic frequency and pulse rate.

A scanner-receiver in an aircraft equipped with paired antenna mounted on the wings will be used to find the signal from each transmitter. The operator can select for a particular frequency or the instrument will automatically scan for all available frequencies.

Determination of the precise location of a transmitter at sea is not necessary to achieve the objectives of the study since the principal interest is in obtaining a frequent inventory of carcasses and decoys present in the area. If a carcass or decoy appears to be present on a beach, effort will be made to determine its precise position and assess the likelihood of its recovery. The approach used will be to fly parallel to the beach over the surf zone. If the transmitter is offshore, the signal will be received by only the outboard antenna. If the transmitter is on the beach or in the surf, the signal will be received by only the inboard antenna. Flight altitude of the tracking aircraft over open water will typically be 3,000 to 5,000 ft. ASL, but will decrease to 500 ft ASL or less near the beach. On subsequent days following the release, a search area will be identified taking into consideration the last known location of transmitters and the results of a trajectory model. The model to be used is the NOAA Oil Spill Simulation Model (OSSM), using the most appropriate current field and winds data.

Because of the great number of radio-tags deployed, a special computer data-logging system will be used for output from the receiver-data processor equipment.

Calculation of the coordinates of the transmitter will be accomplished using a mathematical function describing the decrease in signal amplitude with distance. This relationship must be described for each kind of transmitter.

BIBLIOGRAPHY

Burger, A.E. 1989. Effects of the Nestucca oil spill (January 1989) on seabirds along the southwest cost of Vancouver Island.

Report to Environment Canada. Contract No. KA601-8-4184. 26 pp and Appendices.

Carter, H.R., G. W. Page, and R.G. Ford. 1987. The importance of rehabilitation center date in determining the impacts of the 1986 oil spill on marine birds in central California. Wildlife Journal 10:9-14.

Dobbin, J.A., H.E. Robertson, R.G. Ford, K.T. Briggs, and E.H. Clark II. 1986. Resource damage assessment of the T/V Puerto Rican oil spill incident. Unpubl. report, James Dobbin Assoc. Inc., Alexandria, Virginia.

Fleming, T., D. Varoujean, and S. Speich. 1990. Performance and reliability of radio-tags for Marbled Murrelets. Abstract. Proceedings of Meetings of the Pacific Seabird Group, February 1990, Victoria, B.C., Canada.

Ford, R.G. 1984. Southern California Marine Mammal and Seabird Risk Analysis. Final Report prepared for the Minerals Management Service, U.S. Department of the Interior, by Ecological Consulting. Contract #14-12-0001-30224. 240 pp.

Ford, R.G., J.A. Wiens, D. Heinemann, and G.L. Hunt, Jr. 1982. Modeling the sensitivity of colonially breeding marine birds to oil perturbation. J. Appl. Ecol. 19:1-31/

Ford, R.G., G.W. Page, and H.R. Carter. 1987. Estimating mortality of seabirds from oil spills. Pp. 848-51. In Proc. 1987 Oil Spill Conference, American Petroleum Institute, Washington, D.C.

Ford, R.G. and J.L. Casey. 1989. Preliminary Draft Report: Seabird Mortality Resulting from the Nestucca Oil Spill Incident, Winter 1988-89. Prepared for Washington Department of Wildlife. 37 pp.

Gould, P.D., D.J. Forsell, and C.J. Lensink. 1982. Pelagic distribution and abundance of seabirds in the Gulf of Alaska and the eastern Bering Sea. Fish and Wildlife Service, U.S. Dept. of the Interior. FWS/OBS-82-48.

Page, G.W. and H.R. Carter (eds). 1986. Impacts of the 1986 San Joaquin Valley crude oil spill on marine birds in central

California. Unpubl. report, Point Reyes Bird Observatory, Stinson Beach, California.

Page, G.W., H.R. Carter, and R.G. Ford. 1990. Numbers of seabirds killed or debilitated in the 1986 Apex Houston oil spill in central California. Studies in Avian Biology. In press.

Wiens, J.A., R. G. Ford, D. Heinemann, and C. Fieber. 1982. A statistical analysis of the distribution of seabirds in the vicinity of Kodiak Island, Alaska. In Environmental Assessment of the Alaska Continental Shelf. Final Reports.

Budget: FWS

Personnel	$46.0
Travel	21.5
Contractual	521.1
Commodities	9.4
Equipment	0.0
Total:	$598.0

BIRD STUDY NUMBER 2

Study Title: Surveys to Determine Distribution and Abundance of Migratory Birds in PWS and the Northern GOA

Lead Agency: FWS

INTRODUCTION

This study will continue to examine whether the EVOS caused a decline in the distribution and abundance of water birds in the waters and shorelines affected by the spill. Potential injuries to waterbirds from exposure to the EVOS include direct mortality, changes in behavior, and decreased productivity. Surveys by small boats and airplanes will collect information on the seasonal distribution and abundance of waterbirds in the spill zone for several seasons following the spill. These post-spill data will be compared to data collected using similar methods in prior years to determine whether the oil spill affected waterbird distribution and abundance.

This proposal describes the boat survey and aerial survey work that will be accomplished in the second year of this study. The study will continue portions of Bird Studies Number 6 (Marbled Murrelets) and Number 9 (Pigeon Guillemot), and will also record observations of marine mammals in the study area which could prove valuable to other ongoing studies.

OBJECTIVES

A. Aerial Surveys

1. To determine seasonal distribution and estimate relative abundance of waterfowl and waterbirds in PWS and KP.

2. To compare relative abundance and distribution of waterfowl and other waterbirds in oiled vs. non-oiled areas between historical (1971) and recent (1989 and 1990) surveys. To monitor changes in the distribution and abundance of waterfowl and other waterbirds between oiled and non-oiled areas in PWS and KP.

3. To estimate the long- and short-term recovery rates of waterfowl and waterbird populations impacted by the oil spill.

B. Boat Surveys

1. To determine distribution and estimate abundance (with 95% confidence limits) of waterbirds in PWS and the northern GOA.

2. To test the null hypothesis that estimates of waterbird

relative abundances, using new and comparable historic data, are not significantly lower ($\alpha = 0.05$) in oiled than non-oiled areas in PWS and the northern GOA.

3. To estimate the long- and short-term trends of populations that were determined in previous objectives to be reduced by the oil spill.

4. To test the null hypothesis that the total number of Pigeon Guillemots attending colonies at Naked Island, PWS, following the EVOS is not significantly lower than the total number attending in prior years.

5. To test the null hypothesis that the abundance index of Marbled Murrelets on five transects on the western side of Naked Island, PWS, following the EVOS is not significantly lower than the abundance index on each transect in prior years.

METHODS

A. Aerial Survey Sampling Methods

Three surveys will be conducted during the 1990-1991 oil spill year: the spring survey during May; the fall survey during September; and the winter survey during February. A fourth survey (summer survey during July) may be undertaken. Survey dates are selected to count the spring and fall populations at or near the peak of their migration and to count winter (and possibly summer) populations when they are most stable. Three single-engine fixed-wing aircraft, will be used for each survey.

The aircraft will be flown at approximately 150 feet above water level and 200 meters offshore, following the shoreline as closely as possible given the aircraft's capabilities, and maintaining an airspeed of 95 - 100 mph. All birds and marine mammals will be observed within 200 meters from each side of the aircraft. Date, survey beginning and stop time, wind speed and direction, air temperature, cloud cover, ceilings and visibility will be recorded for each survey date.

Survey weather minimums will be restricted to 1,500 feet or greater ceilings, 10 miles horizontal visibility, surface winds of 15 knots or less, and seas no larger than wavelets.

The entire coastline of PWS and southern KP, including Kachemak Bay, will be surveyed during each of the three seasonal surveys.

The visibility bias associated with counting birds from low flying aircraft will result in an underestimate of population size and bird densities, but this bias will be the same in both oiled and non-oiled areas and remain relatively constant between surveys. Therefore, the bias will have no effect on comparisons between areas and years.

Estimates of waterfowl and waterbird abundance and distribution will be done using direct comparisons appropriate for complete shoreline survey indexes. If a significant change in a species group or individual species (such as sea ducks or goldeneye) is detected, then subsets of data stratified by habitat will be analyzed to assess oil effects in comparable oiled and non-oiled habitat for each survey.

Short- and long-term recovery rates, if there is a significant oil effect, will be calculated using a repeated measures ANOVA. Trends may also be compared using regression techniques.

B. Boat Survey Sampling Methods

Surveys will be conducted from small boats manned by an operator and two observers. Observers will record all birds and marine mammals within 100 meters on each side of the boat within survey transects. The survey window extends approximately 40-50 m ahead of and 100 m above the moving boat. Date and time of survey, and environmental variables including wind velocity and direction, air and water temperature, weather, observation conditions, sea state, tide, presence or absence of oil, and human activity will be recorded for each transect.

a. PWS

A stratified random sampling design, including shoreline, coastal/pelagic and pelagic strata, will be used to meet Objectives 1-3. Approximately 29% of the shoreline and 25% of coastal/pelagic and pelagic plots will be surveyed once in March 1990 and three times (one survey each in June, July and August) during the summer of 1990. Surveys will be conducted jointly with Marine Mammal Study Number 6. All birds and marine mammals within transect boundaries will be recorded.

The shoreline stratum includes all water within 200 m of any shoreline, and will be surveyed by traveling 100 m offshore, parallel to the coast, at 5-10 knots. The shoreline stratum is divided into transects consistent with those used by D. Irons during 1984-1985 surveys.

Coastal/pelagic and pelagic strata consist of plots of water delineated by 5-minute intervals (latitude and longitude) on NOAA charts and exclude any water within 200 m of the coast. Coastal/pelagic and pelagic plots differ in that coastal/pelagic plots include more than approximately 1 nm (nautical mile) of shoreline, whereas pelagic plots contain less than 1 nm of shoreline. For plots that are 5 minutes wide (east to west), two north-south transects extending 100 m on each side of the boat and located 1 minute inside the east and west boundaries of the plot will be steered by a combination of compass heading and LORAN-C coordinates. For plots that are less than 5 minutes wide due to intersection with land, either one or two north-south transect lines will be surveyed, depending on plot size.

b. Kodiak Island

Shoreline and pelagic transects will be surveyed off the west and north coasts of Kodiak Island to meet Objectives 1-3. The shoreline was divided into transects based on habitat type following the criteria of Irons et al. (1988) and then a simple random sample consisting of 25% of the transects was chosen. These shoreline transects, and all pelagic transects surveyed by Forsell and Gould (1981) will be surveyed in July 1990 and February 1991.

c. Naked Island

To meet Objective 4, the number of Pigeon Guillemots in the Naked Island group will be determined by circumnavigating each island in a small boat between 50 and 100 m from shore and counting all Guillemots on land and water. Surveys will be done during peak attendance, (between 0500 and 1000 hours), during the first week in June, when breeding birds are in attendance, and during the last week in July, when non-breeding birds are in attendance as well.

Ancillary observations on Pigeon Guillemot reproduction will be made. Objectives of such observations include nesting success, fledgling weight, the rate at which chicks are fed, and identification of fish species fed to chicks as food.

The number of Marbled Murrelets (and other birds and marine mammals) on five inshore transects on the western side of Naked Island will be counted from a small boat (Zodiac) to meet Objective 5. The transect routes will be those used by Bird Study 9 in 1989, and in three years previous to the oil spill to allow comparison with all previously collected data.

Estimates of waterbird abundance and variances (Objective 1) will be made using ratio estimators and statistics appropriate for stratified random sampling. This technique will be used if the number of birds is positively correlated with transect length. If the correlation between bird numbers and transect length is poor, simple means and variances will be calculated.

Differences in waterbird abundance between oiled and non-oiled areas (Objective 2) will be tested by examining the change in abundance on each transect between 1984 and 1989. One-tailed t-tests or the Mann-Whitney test will be used. If areas are stratified further based on habitat type then ANOVA will be used. ANOVA will be used to make comparisons between pre- and post-oil spill data with respect to oiled and non-oiled areas.

Short- and long-term recovery rates (Objective 3), if there is a significant oil effect, will be analyzed using a repeated measures ANOVA. Trends may also be compared using regression techniques.

The outlier t-test will be used to test whether the number of guillemots counted at Naked Island in 1990 is significantly lower than the mean of mean counts in prior years (Objective 4). Counts will be logarithmically transformed prior to testing.

The outlier t-test will be used to test whether the abundance indices of Marbled Murrelets in 1990 are significantly lower than the mean of mean indices for prior years (Objective 5).

BIBLIOGRAPHY

Alaska Department of Environmental Conservation. 1989. Unpublished preliminary digital maps of oil-impacted shore based on aerial and boat surveys during early ADEC response activities. [ARC/INFO data file].

Bowden, D.C. 1973. Review and evaluation of May waterfowl breeding ground survey. Unpubl. Manu. Fish and Wildlife Service. Anchorage, Alaska. 74 pages.

Butler, W. 1989. Prince William Sound and Kenai Peninsula Migratory Bird Aerial Survey Project. Unpublished data. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Cochran, W.G. 1977. Sampling Techniques. John Wiley and Sons, Inc. New York, New York. 428 pages.

Conant, B., J.G. King, J.L. Trapp, and J.I. Hodges. 1988. Estimating populations of wintering waterfowl in southeast Alaska. U.S. Fish and Wildlife Service, Juneau, Alaska. Unpublished Report. 16 pages.

Dwyer, T.J., P. Isleib, D.A. Davenport, and J.L. Haddock. 1975. Marine Bird Populations in Prince William Sound Alaska. U.S. Fish and Wildlife Service, Anchorage, Alaska. Unpublished Report, 21 pages.

Forsell, D.J. and P.J. Gould. 1981. Distribution and abundance of marine birds and mammals wintering in the Kodiak area of Alaska. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-81/13. 81 pages.

Haddock, J.L., C. Evans, L.W. Sowl, M.E. Isleib, P. Havens, J. Reynolds, and D. Johnson. Unpublished 1971 Prince William Sound aerial survey data. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Hogan, M.E. and J. Murk. 1982. Seasonal distribution of marine birds in Prince William Sound, based on aerial surveys, 1971. U.S. Fish and Wildlife Service, Anchorage, Alaska. Unpublished Report.

Irons, D.B., D.R. Nysewander, and J.L. Trapp. 1988. Prince William Sound sea otter distribution. U.S. Fish and Wildlife Service, Anchorage, Alaska. Unpublished Report, 31 pages.

Irons, D.B., D.R. Nyeswander, and J.L. Trapp. ms. Prince William Sound waterbird distributions in relation to habitat type. U.S. Fish and Wildlife Service, Anchorage, Alaska. 24 pages.

Klosiewski, S. and L. Hotchkiss. 1990. Assessment of injury to waterbirds from the Exxon Valdez oil spill: Surveys to determine distribution and abundance of migratory birds in Prince William Sound and the Northern Gulf of Alaska. Bird Study Number 2. Preliminary Status Report. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Nishimoto, M. and B. Rice. 1987. A re-survey of seabirds and marine mammals along the south coast of the Kenai Peninsula, Alaska during the summer of 1986. U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, Homer, Alaska. Unpublished Report, 79 pages.

BUDGET

Category	Aerial Survey Budget	Boat Survey	Total Budget
Personnel	$59.0	$207.0	$266.0
Travel	5.0	14.0	19.0
Contractual	47.0	64.0	111.0
Commodities	3.0	60.0	63.0
Equipment	0.0	12.0	12.0
Total	$114.0	$357.0	$471.0

BIRD STUDY NUMBER 3

Study Title: Population Surveys of Seabird Nesting Colonies in PWS, the Outside Coast of the KP, Barren Islands, and Other Nearby Colonies.

Lead Agency: FWS

INTRODUCTION

The 1989 oil spill in PWS and its drift to the west along the Alaskan coast prompted resurvey in 1989 of seabird colonies in PWS, the Chiswell Islands, the Barren Islands, sites along the Alaska Peninsula, some sites near Kodiak Island, and the Semidi Islands. Most of these colonies had been censused at least two and up to six different years out of the last 17 years, providing some base line for determining changes that may have occurred on the colonies surveyed. Murres and kittiwakes on one colony site, Middleton Island, have been censused 11 of the last 17 years.

Diving seabirds are known to be easily impacted by oil spills (King and Sanger, 1979). In addition, these species are long-lived with low reproductive rates, thus making any mortality of adults a critical factor in these species' ability to recover from loss. There are at least 320 seabird colonies that occur within the area affected by the oil spill. They contained about 1,121,500 breeding seabirds of which approximately 319,000 were murres (USFWS, Catalog of Alaskan Seabird Colonies--Computer Archives 1986). Some of these colonies are among those most visited by tourists in Alaska. Cliff-nesting seabirds, like murres, are an important part of this human use/tourism.

This year, the study will concentrate more on murre populations and less on other species than it did last year. This will facilitate increased replicate counts and improve statistical evaluation. The breeding season censuses will occur at the Chiswell Islands, Barren Islands, specific sites along the Alaska Peninsula and the Semidi Islands. Egg laying is the accepted time to census murres since their colony attendance is too variable at other times (Hatch and Hatch, 1988; Byrd, 1989; Nysewander, 1989).

OBJECTIVES

Determine whether the numbers of selected species of breeding colonial seabirds within the oiled area have decreased compared to numbers previously censused at these sites. Non-oiled nesting colonies will be surveyed as a control.

METHODOLOGY

Assessment of injury to murre populations is being conducted in four general areas: 1) Chiswell Islands, 2) Barren Islands, 3) Alaska Peninsula sites, and 4) Semidi Islands, a non-oiled control area. Middleton Island is not part of this particular investigation, but an ongoing study at that location will provide numbers of murres present on those colonies for comparison with affected areas. Changes in numbers of breeding adult seabirds will be documented, with primary emphasis placed on murres.

Total counts are not feasible at large colonies like the Semidi and Barren Islands; hence previously established plots will be utilized. Two strategies will be used: 1) counts of adult murres on plots from land-based observation points; and 2) counts from boat-based observation vantage points where land-based observations are not possible. These plots may also serve as a correction factor for total counts or estimates that may be needed for comparison with past estimates.

Specifically, the two strategies used in 1989 will be implemented again in 1990 (Nysewander, 1989), as follows:

1) A combination of total subcolony or island counts and counts of sample plots counted from boats will occur at colony sites like the Barren Islands and Chiswell Islands because the colonies are much larger, in very exposed waters, have a poor history of censusing, and require counts from boats. Previous sample plots were established on the basis of accessibility and visibility.

2) Land-based plots will be continued at the Semidi Islands because these colonies are too large for total counts, and land plots are feasible and have been used for over 10 years. Sample plots were previously selected on the basis of accessibility. The Alaska Peninsula murre colonies will require a combination of both applications since some portions of the colonies are visible from land, but most aspects of the colony will require boat counts.

Colonies will be recensused using standard FWS methodology for either land-based or boat-based counts of seabirds (Byrd 1989; Hatch and Hatch 1988 and 1989; Irons et al. 1987; Nishimoto and Rice 1987). Efforts will be made to complete at least three replicate counts of colonies or plots after eggs are laid. Counts will be conducted on three separate days between the hours of 1000 and 1600. Plot counts and photographs of plots will be used to establish correction factors of total subcolony or island counts, comparisons with past counts of plots, and for evaluation of future recovery or change.

At least three observers will make the counts by binoculars from the boat. Each observer counts each section of the cliff at least two times and all counts are compared to determine if sections of the plot were missed (differences in counts by observers cannot be greater than 5%) and need more replicate counts.

Standard procedures and assumptions used by the FWS for colony counts in the Alaska Maritime National Wildlife Refuge are described by Garton 1988 and Byrd 1989. Several key assumptions are: 1) Plots, by necessity, are not random and selection is based on accessibility; hence this study makes the assumption that counts within plots are representative of the way the counts varied on the entire colony; 2) Counts of plots or entire colonies from boats are very difficult for large colonies and replications of counts by several observers on the same day and different days illustrate the need to refine the accuracy and the variation recorded. This means that even counts of entire colonies are also considered to be indices, but this study assumes that changes in these indices represent the changes occurring in the colony; 3) Counts of things are very unlikely to be normally distributed and are more likely to be skewed and clumped. This type of data requires either very large sample sizes, the use of a non-parametric test, or the data needs to be transformed logarithmically and then tested by the appropriate parametric test. This transformation normalizes the data and is required for valid application of statistical tests on small sample sizes (Fowler and Cohen 1986, D. Robson pers. comm.).

Standard FWS procedures mentioned prefer to compare trends between years using numerous replicate counts where all plots are censused each count day and these counts are replicated on successive days. The average of daily counts on the Semidi Islands will be used to calculate a confidence interval for the estimate as was done on the Semidi Islands data in the past (Hatch and Hatch 1988; Hatch and Hatch 1989). At other sites where there were fewer replicate counts, past procedures which averaged available counts, will be followed. The important question is whether the "after oiling" response is outside the anticipated annual variation in colony numbers that would be expected from past historical data without oiling effects.

BIBLIOGRAPHY

Byrd, G.V. 1989. Seabirds in the Pribilof Islands, Alaska: trends and monitoring methods. M.S. thesis, Univ. of Idaho, Moscow, Idaho. 96pp.

Garton, E.O. 1988. A statistical evaluation of seabird monitoring programs at three sites on the Alaska Maritime National Wildlife Refuge. Univ. of Idaho, Moscow, Idaho. Unpubl. Rept. from contract with the refuge. 15pp.

Fowler, J. and L. Cohen. 1986. Statistics for Ornithologists. British Trust for Ornithology, BTO Guide No. 22, Tring, Hertfordshire. 175pp.

Hatch, S.A. and M.A. Hatch. 1989. Attendance patterns of common and thick-billed murres at breeding sites: implications for monitoring. J. Wildl. Mgmt. 53(2):483-493.

Hatch, S.A. and M.A. Hatch. 1988. Colony attendance and population monitoring of black-legged kittiwakes on the Semidi Islands, Alaska. Condor 90:613-620.

Irons, D.B., D.R. Nysewander, and J.L. Trapp. 1987. Changes in colony size and reproductive success of black-legged kittiwakes in Prince William Sound, Alaska, 1972-1986. U. S. Dept. Interior, Fish and Wildl. Serv., Anchorage, Alaska, Unpubl. Rept. 37pp.

King, J.G. and G.A. Sanger. 1979. Oil vulnerability index for marine oriented birds. Pp. 227-239 _in_ J.C. Bartonek and D.N. Nettleship eds. Conservation of marine birds of northern North America. U. S. Fish and Wildl. Serv., Washington, D.C. 319pp.

Nishimoto, M. and B. Rice. 1987. A re-survey of seabirds and marine mammals along the south coast of the Kenai Peninsula, Alaska during the summer of 1986. U. S. Fish and Wild. Serv., Alaska Maritime National Wildl. Refuge, Homer, Alaska. Unpubl. Rept. 79pp.

Nysewander, D. 1989. Population surveys of seabird nesting colonies in Prince William Sound, the outside coast of the Kenai Peninsula, Barren Islands, and other nearby colonies. U.S. Fish and Wildlife Serv., Alaska Maritime National Wildlife Refuge, Homer, Alaska. Unpubl. Rept. 52pp.

U. S. Fish and Wildlife Service. 1986. Catalog of Alaskan seabird colonies--computer archives. U.S. Fish and Wildl. Serv., Migratory Bird Management, Anchorage, Alaska 99503.

BUDGET: FWS

Personnel	$87.5
Travel	12.3
Contractual	111.2
Commodities	24.1
Equipment	16.0
Total	$251.1

BIRD STUDY NUMBER 4

Study Title: Assessing the Effects of the EVOS on Bald Eagles

Lead Agency: FWS

INTRODUCTION

The area affected by the EVOS provides year-round habitat for approximately 5000 adult bald eagles and seasonal habitat for an additional estimated 2500 immatures. An unknown number of bald eagles from breeding areas in south-central Alaska probably also winter in the PWS.

Bald eagles are closely associated with intertidal habitats that have been heavily impacted by the EVOS. Nearly all nests in the spill area occur within 100 meters of the beach and eagles commonly forage in intertidal habitats on fish and marine invertebrates. Eagles that breed elsewhere, but spend winters in the spill area, will also use the affected intertidal habitats for foraging.

Contamination of these intertidal habitats may result in serious impacts to bald eagles. Effects may include direct mortality of adults and immatures from ingestion of oil-contaminated food or from preening of oil from feathers. Eagles that become heavily oiled or entrapped in oil may die. Mortality of embryos can occur when eggs are contaminated with oil carried to the nests on the plumage of the adults. Decreases in the abundance of prey such as herring, eulachon, salmon, or marine invertebrates may increase the vulnerability of eagles to starvation or to disease induced by weakened physical condition. Significant losses of breeding adults, eggs, nestlings and non-breeding eagles are expected.

This study is designed to document the magnitude and duration of these impacts and determine whether these impacts are a result of oil contamination. Estimates for the number of eagles occupying the spill area after the spill will be compared with historical data to identify changes in the population. Occupancy and reproduction surveys will be conducted to determine productivity and to document differences in production between oil-affected and non-oiled areas. Nestling and adult bald eagles from oiled and non-oiled areas will be radio-tagged and monitored to estimate survival rates, distribution and exposure to oiled areas, and determine causes of mortality.

Because eagles mature slowly and are long-lived, impacts to the population may not be readily apparent. It may require an extended period of study to substantiate the long-term impact of oil contamination on bald eagles.

OBJECTIVES

A. Estimate numbers of resident bald eagles such that the estimate is within 10% of the actual size 95% of the time; determine whether changes in population size have occurred in the oil-affected areas since 1982 and test whether the change in number of eagles in oil-affected areas is different than changes in non-oiled areas.

B. Test the hypothesis that productivity of bald eagles is the same in oiled and non-oiled areas (a = 0.05).

C. Test the hypothesis that survival rates are the same for bald eagles in oiled and non-oiled areas (a = 0.05).

D. Determine toxic and sublethal effects of oiling on eagles and eggs.

METHODS

Population surveys (Objective A). Surveys of randomly selected plots roughly 50 square miles in size will be conducted from Malaspina Glacier to Cape Elizabeth in early May, following methodology discussed in Hodges et al. (1984). All shorelines in each selected plot will be flown at an altitude of about 200 feet and an airspeed of 90-100 knots using fixed-wing aircraft. Eagles will be classified as either white-headed or immature. "White-headed" eagles will include sexually mature adults and near-adults that have predominately white heads. This survey will not directly estimate the number of immatures, therefore we will assume that our ability to detect all age classes is equal for birds in flight, and a ratio of adults to immatures observed flying will be used to estimate the number of immatures.

A parametric two-sample t-test (Steel and Torrie 1960) which does not require equal variances will be used to test the above hypotheses. Analysis of variance will be used for multiple comparisons. Assumptions necessary for valid application of the t-test will be checked (e.g., test for normality). If assumptions are violated, we will use either an appropriate transformation or an equivalent non-parametric test.

Productivity surveys (Objective B). Two surveys to determine productivity will be conducted in the oil spill area (PWS, KP, Kodiak/Afognak Islands and the Alaska Peninsula) and in the Copper River Basin, an area used by eagles that may winter in the oil spill area. The first aerial survey will be flown during mid-May to estimate the number of adults that attempt to breed. The second survey will be flown in mid-July to estimate the number of successful nests and the number of young produced. Surveys will be conducted from helicopter at an altitude of 80-200 feet at 40-60 kts. airspeed to determine nest status. Data collected will include number of nests surveyed, number of nests occupied, number of nests that successfully produce young, and number of young produced (Postupalsky 1974).

Nests that fail will be climbed to collect dead eggs or nestlings and to identify the cause of failure.

The hypothesis that there is no difference in the observed production among treatment groups compared with what would be expected if nests were assigned randomly to each of the treatment groups will be tested using a non-parametric permutation test.

Beaches within 1/2 mile of bald eagle nest sites are representative of bald eagle home range in coastal Alaska (USFWS, unpubl. data). The length of shoreline within the "home range" will be measured and the lengths of segments classified as heavily, moderately, lightly, or unoiled will be totalled for each "home range". These values will be used in a multiple regression to identify relationships among the degree of oiling, nest occupancy, and productivity parameters. Data on productivity from the Copper River Basin will be compared with data from coastal areas. Productivity data from southeastern Alaska will also be used for comparative purposes.

<u>Survival Studies (Objective C)</u>: To estimate survival rates, 60 eagles (15 adults and 15 nestlings each from oiled and non-oiled areas) will be tagged with radio transmitters (Pollock et al. 1989). Approximately 15 adult bald eagles will also be radio-tagged in the Copper River Basin to demonstrate whether eagles breeding inland winter in areas affected by the oil spill. Weekly aerial flights will be made to relocate the transmitters using standard telemetry techniques (Gilmer et al. 1981) and to document eagle numbers, distribution and mortality within the study area. Dead eagles will be retrieved and necropsied to determine the cause of death.

A Z-test (Bart and Robson 1982) will be used to test for significant differences in survival rates between eagles marked in oiled areas and eagles marked in unoiled areas. This Z-test requires the use of a transformation of the survival rate and standard error to normalize its distribution and allow use of a Z statistic to test for differences in survival rates. Accurate relocations of individual radio-marked eagles will allow appropriate classification of eagles into treatment groups based on the proportional amount of time they were located in oiled or unoiled areas.

<u>Toxic and Sublethal Effects of Oiling (Objective D)</u>: All eagles found dead will be collected and necropsied to determine the cause of death, to note the extent of oiling and to look for ingested oil

or other signs of oil contamination. Tissue samples from the collected specimens will be analyzed for contaminants.

Unhatched eggs collected from failed nests will be examined for oil contamination of eggshells, egg contents, and the presence and development of embryos.

Blood samples from free-flying birds will be collected by properly trained personnel and analyzed to determine concentrations of hydrocarbons and other contaminants associated with oil contamination. Approximately equal numbers of bald eagles will be sampled from oiled and non-oiled areas. Blood samples will also be analyzed for standard blood chemistry profiles, which will help identify sublethal impacts.

Significant differences in levels of contaminants and blood characteristics between bald eagles from oiled and non-oiled areas will be tested using a 2-sample t-test (a = 0.05). Assumptions necessary for valid application of the t-test will be checked (e.g., test for normality). If assumptions are violated, either an appropriate transformation or an equivalent non-parametric test will be used.

BIBLIOGRAPHY

Bart, J. and D. S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. Ecology 63:1078-1090.

Bortolotti, G. R. 1984. Physical development of nestling bald eagles with emphasis on the timing of growth events. Wilson Bull. 96:524-542.

Carpenter, in press.

Gilmer, D. S., L. M. Cowardin, R. L. Duvall, L. M. Mechlin, C. W. Shaiffer, and V. B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U. S. Fish and Wildlife Service Resource Publication 140. 19 pp.

Hodges, J. I., J. G. King, and R. Davies. 1984. Bald eagle breeding population survey of coastal British Columbia. J. Wildl. Manage. 48:993-998.

Kaplan, E. L. and P. Meier. 1958. Non-parametric estimation from incomplete observations. J. Am. Stat. Assoc. 53:457-481.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53:7-15.

Postupalsky, S. 1974. Raptor reproductive success: some problems with terminology. Raptor Research Report 2:21-31.

Steel, R.G.D. and J.H. Torrie. 1960. Principals and procedures in statistics. McGraw-Hill, New York. 481 pp.

Budget: FWS

Personnel	$120.0
Travel	17.0
Contractual	503.0
Commodities	25.0
Equipment	10.0
Total	$675.0

BIRD STUDY NUMBER 5

Study Title: Impact Assessment of the EVOS On Peale's Peregrine Falcons

Lead Agency: FWS

Cooperating Agency: ADF&G

INTRODUCTION

Peale's falcons (Falco peregrinus pealei) occur along the southern coast of Alaska from the Aleutian Islands through southeastern Alaska. The goal of this project is to determine whether the EVOS has had, or will have, a measurable impact on Peale's peregrine falcons in PWS and coastal KP.

Peale's falcon populations in Alaska have been estimated at between 500-600 pairs (Schempf 1989, Ambrose pers. comm). An estimated 40-60 pairs inhabit PWS and coastal KP (Janik & Schempf 1985) and another 20-30 pairs occur in the Kodiak Archipelago, upper AP, and CI area, for a total of 60-90 pairs in coastal habitat affected by EVOS.

Alcids, small gulls, and petrels are prime peregrine prey species that became oiled as a result of EVOS and may be taken by falcons. Oil transferred to peregrine falcons could affect individuals and the population through: 1) coating of feathers and the resulting loss of insulation and flight capabilities; 2) reduced reproduction due to ingestion of hydrocarbons and trace-metals that affect the breeding physiology of adults; 3) reduced reproduction due to transfer of oil from feathers of incubating adults to eggs; 4) mortality of individuals due to toxicity of oil; and 5) reduced reproduction due to reduced prey availability when prey populations are impacted.

This project will continue to provide information on the number of nest sites occupied by Peale's falcons and their productivity. These data, in combination with historical data for this area, will provide a basis to evaluate whether changes have occurred in the distribution, abundance, and/or productivity of falcons. Examination of secondary wing feathers taken from young, along with prey remains and eggs collected from occupied aerie, will provide evidence of whether crude oil was ingested or absorbed by falcons. Analysis of wing feathers and prey remains collected several months after the oil spill will provide information on the bioaccumulation of trace-metals from crude oil, in marine and terrestrial food chains.

OBJECTIVES

A. Test the hypothesis that nest site occupancy and productivity are lower in the project area as a result of EVOS than in other populations.

B. Test the hypothesis that the quantities of vanadium and nickel in peregrine feathers are the same for birds nesting in oiled and non-oiled areas.

C. Count and identify prey remains collected at aeries.

D. Test the hypothesis that the level of pesticide contamination of egg clutches in the project area is less than contamination levels reported in scientific literature as causing reproductive failures in peregrine falcons.

METHODS

The project area will include the mainland shore and islands of PWS from Cape Hinchinbrook along the southern coast of the KP through Kachemak Bay.

Two surveys of the project area will be conducted. Guidelines have been formulated to standardize survey techniques, terminology, and data collection. The initial survey, to determine presence or absence of peregrines at coastal bluffs and to collect fresh egg samples for contaminant analysis, will take place in mid-April. A boat and helicopter will be used for transportation. If a helicopter is used at sites with large concentrations of cliff nesting seabirds, it will land far enough away from bluffs to minimize disturbance. Observers will approach on foot to survey potential nesting habitat.

The second survey via helicopter, in June, will cover the same area, but will focus on the sites determined to be occupied by peregrine falcons during the initial survey. Nests will be located by observers on the ground and then visited to collect feather samples and to band nestlings with standard aluminum bands. Secondary feather samples from young will be collected at aeries during the June nest survey. Prey remains and addled or broken eggs will be collected at nest sites. During both surveys, investigators will document oil on falcons and look for bands on adults to learn where they were banded.

Twenty-five prey remains will be examined for hydrocarbon contamination. Samples collected for hydrocarbon analysis will be handled carefully. Chain-of-custody will be maintained for all samples, and they will be stored in a secure facility at ADF&G in Anchorage until they can be sent to an approved laboratory for analysis.

Feathers grown by nestling peregrine falcons should contain trace-elements in an array of concentrations unique to the local ecosystem (Parrish et al. 1983). High levels of nickel and vanadium have been associated with North Slope crude oil and these trace-metals are bioaccumulated in marine and terrestrial food chains (Minerals Management Service 1988). Predators at the top of food chains, such as the peregrine falcon, may encounter toxic levels of trace-metals because these elements are concentrated with each step up the food chain. Toxic quantities of trace-metals have been implicated in population declines of peregrines and other raptors (Newton 1979). Elevated levels of nickel in the diet will produce physiological effects similar to lead or mercury poisoning such as central nervous system disorders and reduced reproductive success (Williams, pers. comm.) Traces of these metals can be measured efficiently in birds feathers by instrumental neutron-activation analysis (INAA) (Wainerdi and Dubeau 1963). Feather samples from peregrines not influenced by the oil spill from other regions of the state will serve as controls.

Approximately 30 feather samples will be collected for trace-metal analysis. The distal 1 cm of the fifth secondary remige will be collected from adult and nestling peregrines for INAA as described by Parrish et al. (1983). Feather samples will be labeled and preserved. Chain-of-custody will be maintained for all samples and they will be stored in a secure facility at ADF&G in Anchorage until they can be sent to an approved laboratory for INAA.

The decline of peregrine populations in North America during the 1950's through the early 1970's was linked to organochlorine pesticides (Hickey 1969). Substantial levels of biocides have been found in Peale's falcons in coastal British Columbia and it has been suggested that the depressed reproductive success on Langara Island was largely due to the effects of pollutants (Nelson & Myres 1976). Since trace-metals may affect reproduction in peregrines, similar to organochlorine pesticides, a pesticide monitoring program would help identify which factors are involved. Thus collection of fresh eggs is necessary for pesticide analysis.

Historically, about 35 aeries are thought to be occupied each year in the project area. The collection of 10 eggs will provide an adequate sample without significantly impacting productivity.

Chain-of-custody will be maintained for all samples and they will be stored in a secure facility until they can be sent to an approved laboratory for chemical analysis as described by Cromartie et al. (1975) and Kaiser et al. (1980).

Data analysis to achieve objective A involves a comparison of site occupancy and productivity in the project area with other peregrine populations. In order to control for yearly variation in brood size, the mean brood size of peregrines in Norton Sound for 1989 and 1990, will be compared to the historical data with an analysis of variance (ANOVA) (Snedecor and Cochran 1980) using the appropriate linear contrasts to test the hypothesis that the mean brood sizes are equal between the historical data and Norton Sound. Assuming the Norton Sound data do not differ from the historical data, a two sample T-test will be used to test the null hypothesis that mean brood size in PWS in 1990 is greater than or equal to mean brood size in Norton Sound. The alternative hypothesis is that mean brood size in 1990 in PWS is less than mean brood size in Norton Sound. A similar analysis will be done for the 1990 productivity data.

ANOVA and a two sample T-test have the following assumptions:

1) The samples are random and independent;
2) The distribution of the different means is normal; and
3) The variances of the samples are equal.

A Q-Q plot (Hoaglin et al. 1985) of the raw data will determine whether the data is approximately normal, in which case the Central Limit Theorum will insure that assumption two is met. If assumption two is not met, a non-parametric test will be employed (Conover 1980). Bartlett's statistic will be used to test assumption three and a transformation employed, if necessary, to meet this assumption.

Two separate Fisher's exact test (Ostle and Mensing 1982) will be used to determine whether PWS had lower nest occupancy rates than Norton Sound for 1989 and 1990.

Data analysis to achieve objective B involves a two sample T-test (Snedecor and Cochran 1980) to determine whether trace-metal concentrations are lower in the project area than outside the project area. The null hypothesis is that nickel and vanadium concentrations in peregrine feathers from the project area in 1990 is less than or equal to nickel and vanadium concentrations in peregrine feathers from elsewhere in Alaska in 1990. The alternative hypothesis is that nickel and vanadium concentrations in peregrine feathers from the project area in 1990 were greater than nickel and vanadium concentrations in peregrine feathers from elsewhere in Alaska in 1990.

For objective C, if hydrocarbon prey remains are observed, an estimate of the proportion of contaminated prey remains will be estimated at a 95% confidence interval. The confidence intervals require that the proportion be normally distributed. If necessary, transformations will be used to meet this assumption (Snedecor and Cochran 1980).

The null hypothesis contained in Objective D states that levels of pesticide contamination of peregrine eggs collected in the project area in 1990 are greater than or equal to the levels of pesticide contamination of peregrine eggs reported in literature as causing reproductive failures (Peakall et al. 1975). The alternative hypothesis states that levels of pesticide contamination of peregrine eggs collected in the project area in 1990 are less than the reported levels of pesticide contamination of peregrine eggs associated with reproductive failures. A one-tailed, one sample T-test (Snedecor and Cochran 1980) will be used to test this hypothesis. This test assumes the sample was randomly collected and the mean has a normal distribution. If necessary, either a transformation will be used to meet the normality assumption or the Wilcoxon Signed Ranks test (Conover 1980) will be employed to test this hypothesis.

BIBLIOGRAPHY

Conover, W. J. 1980. Practical nonparametric statistics, 2nd ed. John Wiley & Sons, New York, N. Y. 493 pp.

Cromartie, E., W. L. Reichel, L. N. Locke, A. A. Belisle, T. E. Kaiser, T. G. Lamont, B. M. Mulhern, R. M. Prouty, and D. M. Swineford. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for Bald Eagles, 1971-72. Pestic. Monit. J. 9: 11-14.

Hickey, J. J. (ed) 1969. Peregrine Falcon Populations: their biology and decline. Univ. of Wisconsin Press, Madison. 596 pp.

Hoaglin, D. C., F. Mosteller, and J. W. Tukey. 1985. Exploring data tables, trends, and shapes. John Wiley & Sons, New York, N. Y. 527 pp.

Janik, C. A. and P. F. Schempf. 1985. Peale's peregrine falcon (_Falco peregrinus pealei_) studies in Alaska, June 12-24, 1985. Raptor Management Studies, U.S. Fish and Wildlife Service, Juneau, Alaska. 12 pp.

Kaiser, T. E., W. L. Reichel, L. N. Locke, E. Cromartie, A. J. Krynitsky, T. G. Lamont, B. M. Mulhern, R. M. Prouty, C. J. Stafford, and D. M. Swineford. 1980. Organochlrine pesticide, PCB, and PBB residues and necropsy data for Bald Eagles from 29 states - 1975-77. Pestic. Monit. J. 13: 145-49.

Minerals Management Service. 1988. Draft environmental impact statement, Outer Continental Shelf Mining Program, Norton Sound Lease Sale. Minerals Management Service, Anchorage, Alaska.

Nelson, R. W. and M. T. Myres. 1976. Declines in populations of peregrine falcons and their seabird prey at Langara Island, British Columbia. Condor 78: 281-293.

Newton, I. N. 1979. Population ecology of raptors, Buteo Books, Vermillion, South Dakota. 399 pp.

Ostle, B. and R.W. Mensing. 1982. Statistics in research 3rd ed. The Iowa State Univ. Press, Ames IA. 596pp.

Parrish, J. R., D. T. Rogers, Jr., and F. P. Ward. 1983. Identification of natal locales of peregrine falcons (*Falco peregrinus*) by trace-element analysis of feathers. Auk 100: 560-567.

Peakall, D. B., T. J. Cade, C. M. White, and J. R. Haugh. 1975. Organochlorine residues in Alaskan peregrines. Pestic. Monit. J. 8: 255-260.

Schempf, P. F. 1989. Raptors in Alaska. Pages 144-54 in proceedings of the western raptor management symposium and workshop. National Wildlife Federation, Washington, D. C. 320 pp.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods, 7th ed. Iowa State University Press, Ames, Iowa. 507 pp.

Wainerdi, R. E. and N. P. DuBeau. 1963. Nuclear activation analysis. Science 139: 1027-1033.

Personal Communications

Ambrose, R. E. U.S. Fish and Wildlife Service, Endangered Species Branch, Fairbanks, Alaska.

Williams, D. Quantum Medicine, Eagle River, Alaska.

BUDGET: FWS

Personnel	$ 32.2
Travel & per diem	3.5
Services	69.5
Commodities	2.5
Equipment	0.0
TOTAL	$107.7

BIRD STUDY NUMBER 11

Study Title: Injury Assessment of Hydrocarbon Uptake by Sea Ducks in PWS

Lead Agency: FWS

Cooperating Agency: ADF&G

INTRODUCTION

This study will focus on the effects of petroleum hydrocarbon ingestion by Harlequin Ducks (Histronicus histronicus), Barrow's Goldeneyes (Bucephala islandica), Common Goldeneyes (Bucephala clangula), Black Scoters (Oidemia nigra), and Surf Scoters (Melanitta perspicillata) in PWS as a result of the EVOS. PWS is a major wintering area for these sea duck species (Isleib and Kessel, 1973). It is also an important migration area for sea ducks in spring and fall and a breeding site for resident Harlequin Ducks during the summer (Hogan, 1980). Harlequin Ducks in particular, because of their resident status and intertidal foraging habits, are considered substantially at risk to effects of the EVOS (King and Sanger, 1979). Goldeneyes and Surf Scoters, although migratory, are also at risk because of their intertidal and subtidal foraging habits.

The five sea duck species included in this plan are heavily dependent on intertidal and subtidal marine invertebrates (Vermeer and Bourne, 1982). Surf Scoters and goldeneyes utilize blue mussels (Mytilus) and, like Harlequins, consume a wide variety of clams, snails, and limpets (Koehle, Rothe and Dirksen, 1982; Dzinbal and Jarvis, 1982). Bivalves, particularly blue mussels, and small clams (Macoma) are well-known for their ability to concentrate pollutants at high levels (Shaw et al., 1976). The EVOS may cause severe damage to marine invertebrates that support sea ducks throughout the year (Stekoll, Clement, and Shaw, 1980) and bioaccumulation in the food chain may result in uptake of petroleum hydrocarbons by sea ducks over a long period (Dzinbal and Jarvis, 1982; Sanger and Jones, 1982). This study will determine levels of petroleum hydrocarbon ingestion by sea ducks, and will predict resultant physiological and life-history effects (Hall and Coon, 1988). A predictive model may be constructed for sea duck reproductive losses, for instance, based upon physiological effects of petroleum contamination resulting from the EVOS. Pre-oil spill baseline data is available on petroleum contaminant levels of Harlequin Ducks in PWS (Irons, FWS, pers. comm.).

OBJECTIVES

A. Continue to develop a data base describing food habits of the five species of sea ducks in PWS.

B. Obtain data from other NRDA studies of petroleum hydrocarbon levels in marine invertebrates, particularly blue mussels, from the PWS area; Relate this data to the levels of petroleum hydrocarbons found by chemical analysis of invertebrates in gut samples from sea ducks collected in oil spill and control areas; and Test the hypothesis (at alpha = 0.05) that the incidence of petroleum hydrocarbons in gut samples from collected sea ducks is higher in the oil spill areas than in the control areas investigated in 1989-90 (Oil Year 1).

C. Estimate by chemical analysis the petroleum hydrocarbon levels in collected sea duck tissues and body fluids within 10% of the actual value 95% of the time.

D. Test the hypothesis (at alpha = 0.05) that the incidence of petroleum hydrocarbons in tissues of collected sea ducks is significantly higher in 1989-91 in the oil spill areas than in the control areas.

E. Estimate the ingested petroleum hydrocarbon effects on morbidity, mortality, and reproductive potential of sea ducks. This information may be related to other studies to identify changes in abundance and distribution within the affected areas.

METHODS

This study will compare levels of petroleum hydrocarbons in tissues of five species of ducks collected in four study areas. The areas exposed to petroleum are western PWS and southwestern Kodiak Island. The unexposed control sites are southeastern PWS and southeastern Alaska, north of Juneau. Only PWS and the Juneau control site are to be investigated in Oil Year two (March 1990-February 1991). Tissues will be collected for evidence of either histopathology or chemical contamination. Additional seaducks will be collected in "clean" areas within western PWS. This is to provide a secondary control for ducks collected at known sites for heavy oiling of seaduck intertidal forage species.

Seaduck collection in oiled areas of PWS will be integrated with the collection sites of blue mussels in oiled areas in order to demonstrate that seaducks feed in contaminated areas on contaminated prey. Ten such sites are located in western PWS. At each site where petroleum exposure status is documented for intertidal organisms, approximately ten Harlequin Ducks are to be collected in the summer of 1990. These ducks will be sampled for petroleum contamination of food items in the proventriculus, as well as histopathology.

Data on petroleum hydrocarbon levels in marine invertebrates (especially blue mussels) and the degree of oiling at selected sites will be acquired from the Fish/Shellfish Studies 1 and 13, the Coastal Habitat Study, the Air/Water Studies, and Technical Services Study Number 3.

ANOVA (Snedecor and Cochran, 1980) will be used to test the hypothesis that incidence of petroleum hydrocarbons in gut samples from collected sea ducks is higher in the oil spill areas than in the control areas.

Cumulative logit loglinear models (William and Grizzle, 1972; Agresti, 1984) on a per species basis will be used to model the incidence of petroleum hydrocarbons using the area in which collected as the explanatory variable. Hypotheses concerning differences by area in incidence of petroleum hydrocarbons will be tested with a conditional likelihood ratio statistic for nested models (Agresti, 1984). A Bonferroni (Snedecor and Cochran, 1980) Z-statistic (Agresti, 1984) will be used to determine the nature of the differences among areas if the main effect is significant.

Physiological effects will be classified as none, slight, moderate or severe. Loglinear models (Agresti, 1984) will be used to model the distribution of physiological classification by area by species. A conditional likelihood ratio statistic for nested models will be used to test the hypothesis that physiological classification is independent of area. If area and physiological classifications are dependent, a Bonferroni (Snedecor and Cockran, 1980) Z-statistic (Agresti, 1984) will be used to determine differences among areas while controlling for physiological effect.

If possible, an exact test for contingency tables (Agresti, et al, 1990) with ordered responses will be used to determine whether ducks in the oiled area were in significantly poorer physiological condition than ducks in the control area. If it is not feasible to perform the exact test because of unavailability of appropriate methodology, a cumulative logit analysis (Agresti, 1984) will be used to test this hypothesis.

Tissues will be collected for either chemical analysis (presence, absence, or degree of petroleum residue) or histopathology. Results will be compared to unexposed specimens from "clean" (unexposed control) areas. Choice of materials and tissues, handling, and discussion of results will follow published guidelines for interpreting residues of petroleum hydrocarbons in wildlife tissues (Hall and Coon, 1988).

BIBLIOGRAPHY

Agresti, A. 1984. Analysis of ordinal categorical data. John Wiley & Sons, New York. 287 pp.

Agresti, A., C.R. Mehta, and N.R. Patel. 1990. Exact inference for contingency tables with ordered categories. J. Amer. Statist. Assoc. 85: in press.

Dzinbal, K.A. and R.L. Jarvis. 1982. Coastal feeding ecology of Harlequin Ducks in PWS, Alaska, during summer. pp. 6 - 10 in Marine birds: their feeding ecology and commercial fisheries relationships. Nettleship, D.A., G.A. Sanger, and P.F. Springer, eds. Proc. Pacific Seabird Group Symp., Seattle, WA., 6 - 8 Jan. 1982. Can. Wildl. Serv. Spec. Publ.

Sanger, G.A. and R.D. Jones, Jr. 1982. Winter feeding ecology and trophic relationships of Oldsquaws and White-winged Scoters on Kachemak Bay, Alaska. pp. 20 - 28 in Marine birds: their feeding ecology and commercial fisheries relationships. Nettleship, D.A, G.A. Sanger, and P.F. Springer, eds. Proc. Pacific Seabird Group Symp., Seattle, WA., 6 - 8 Jan 1982. Can. Wildl. Serv. Spec. Publ.

Hall, R.J. and N.C. Coon. 1988. Interpreting residues of petroleum hydrocarbons in wildlife tissues. U.S. Fish and Wildl. Serv., Biol. Rep. 88(15). 8 pp.

Hogan, M.E. 1980. Seasonal habitat use of Port Valdez, Alaska by marine birds. Unpublished administrative report. U.S. Fish and Wildl. Serv., Anchorage, Ak. 25 pp.

Isleib, M.E. and B. Kessel. 1973. Birds of the North Gulf Coast - Prince William Sound Region, Alaska. Biol. Pap. Univ. Alaska 14.

King, J.G. and G.A. Sanger. 1979. Oil vulnerability index for marine oriented birds. pp. 227-239 in J.C. Bartonek and D.N. Nettleship (eds.). Conservation of marine birds in northern North America. U.S. Fish and Wildl. Serv., Wildl. Res. Rep. 11. Washington, D.C.

Koehl, P.S., T.C. Rothe, and D.V. Derksen. 1982. Winter food habits of Barrow's Goldeneyes in southeast Alaska. pp. 1 - 5 in Marine birds: their feeding ecology and commercial fisheries relationships. Nettleship, D. N., G.A. Sanger, and P.F. Springer, eds. Proc. Pacific Seabird Group Symp., Seattle, WA., 6-8 Jan. 1982. Can. Wildl. Serv. Spec. Publ.

Sanger, G.A. and R.D. Jones, Jr. 1982. Winter feeding ecology and trophic relationships of Oldsquaws and White-winged Scoters on Kachemak Bay, Alaska. pp. 20-28 in Marine birds: their feeding ecology and commercial fisheries relationships. Nettleship, D.N., G.A. Sanger, and P.F. Springer, eds. Proc. Pacific Seabird Group Symp., Seattle, WA., 6-8 Jan. 1982. Can. Wildl. Serv. Spec. Publ.

Shaw, D.G., A.J. Paul, L.M. Cheek, and H.M. Feder. 1976. *Macoma balthica*: an indicator of oil pollution. Mar. Poll. Bull. 7 (2): 29-31.

Snedecor, G.W. and W. G. Cochran. 1980. Statistical methods. Iowa State University Press. Ames, Iowa. 507 pp.

Stekoll, M.S., L.E. Clement, and D.G. Shaw. 1980. Sublethal effects of chronic oil exposure on the intertidal clam *Macoma balthica*. Mar. Biol. 57: 51-60.

Vermeer, K. and N. Bourne. 1982. The White-winged Scoter diet in British Columbia: resource partitioning with other scoters. pp. 30 - 38 in Marine birds: their feeding ecology and commercial fisheries relationships. Nettleship, D.A.,G.A. Sanger, and P.F. Springer, eds. Proc. Pacific Seabird Group Symp., Seattle, WA., 6-8 Jan. 1982. Can. Wildl. Serv. Spec. Publ.

Williams, O.D. and J.E. Grizzle. 1972. Analysis of contingency tables having ordered response categories. J. Amer. Statist. Assoc. Vol. 67: 55-63.

BUDGET: FWS

Salaries	$75.0
Travel	25.0
Contracts	35.0
Supplies	5.0
Equipment	10.0
TOTAL	$150.0

BIRD STUDY NUMBER 13

Study Title: Preliminary Survey of Passerine Birds in PWS to Assess Impact of the EVOS.

Lead Agency: FWS

Cooperating Agency: ADF&G

INTRODUCTION

Several year-round resident passerine species are heavily dependent upon shoreline and intertidal areas in PWS, and may have become oiled and suffered injury. These species include the gray jay, (Perisoreus canadensis), Steller's jay (Cyanocitta Steller), black-billed magpie (Pica pica), common raven (Corvus corax), northwestern crow (Corvus caurinus), and others. Other migratory passerines that use intertidal and shoreline areas also may be similarly affected by oil contamination. These passerines include swallows (Hirundini dae), thrushes (Muscicap idea), several species of blackbirds and sparrows (Emberizidae), water pipits (Motacillidae). These birds occur in the hundreds of thousands. In addition to direct lethal effects of oiled plumage, birds may be subject to sublethal effects of oil contamination, which could affect overall health and reproductive potential. Passerine species have major intrinsic and recreational (viewing) value.

This study is a reconnaissance survey only. It is designed to provide preliminary information that will assist in determining whether additional, more rigorous, studies of passerines are needed. It was originally proposed in the 1989 damage assessment plan to collect a wider scope of information. However, that study was not implemented because of logistical constraints that arose during the 1989 field season.

OBJECTIVES

A. Observe, record, and report the presence or absence of passerine species in oiled and non-oiled study sites in PWS.

B. Compare count data for 1990 between oiled and non-oiled sites.

C. Compare count data for 1990 with historical data.

METHODS

Oiled and non-oiled shores will be selected for survey, with selection cognizant of available data and logistical support. Observations of passerines will be recorded along oiled and non-oiled beaches on Perry Island in PWS.

Counts and observations will be made from stationary locations and transects that were established and surveyed in previous years. This will allow comparison between pre-oiled years, 1982-86, and post-oiled years 1989-90.

BUDGET: FWS

Personnel	$ 3.0
Travel	0.5
Contracts	5.2
Supplies	0.8
Equipment	0.5
Total	$10.0

ASSESSMENT OF DAMAGE TO HISTORIC PROPERTIES AND ARCHEOLOGICAL RESOURCES

Lead Agency: USFS

Cooperating Agencies: DNR, FWS, NPS

INTRODUCTION

Holocene richness and diversity of resources resulted in the development of the largest prehistoric populations in Alaska along the Pacific mainland and island coasts. Kodiak Island had the largest, most dense prehistoric population of Eskimo peoples in the world. Similar ecological abundance suggests PWS and mainland coasts also supported major human populations. The region of oiled beaches includes large areas where few archeological surveys have been done. To determine damage, specific information is needed on the location, number, and character of historic sites within the EVOS area. This information is obtainable through intensive on-the-ground sample surveys and direct testing.

OBJECTIVES

This study includes activities designed to identify and quantify injury to cultural resources from a scientific standpoint and to develop the foundation for a meaningful program to restore and rehabilitate archeological resources. To determine the injury caused by the spill the study will focus on the following:

A. Impacts on soil chemistry (pH, Calcium, Phosphate)

B. Impacts on soil structure and inclusions (stratigraphy; charcoal)

C. Impacts on artifacts including petroglyphs, bone, wood, ceramic, fiber and shell

D. Impacts on vegetative cover of sites, including new or increased erosion on the sites

E. Occurrence of theft or vandalism on sites, including new or increased incidences

METHODS

1. Activities will be performed in a manner consistent with the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation (48 Fed. Reg. 44716-44740, September 29, 1983).

2. Through a literature search and in-field surveys, an estimate of the number, type, character, and the significance of

historic properties in the area affected by the oil spill will be determined.

3. Develop topologies based on site type, time period, and location.

4. Using the topologies developed, a representative sample of historic properties types and locations to be investigated for impacts, will be selected. The sample will include sites in non-oiled areas to serve as control sites.

5. Conduct archeological investigations at the selected sites and locations.

6. Oil spill response workers and government employees will be interviewed concerning impacts to historic properties and archeological resources.

7. A laboratory analysis of the effects of the oil on the physical characteristics of the soil column will be performed. Attention will be given to its component parts to determine changes in preservation, soil compaction, stratification, and obscuration of the stratigraphy, as well as leaching and the chemical breakdown of organic materials.

8. Radiocarbon age determinations and soil sample analyses for pH, calcium, and phosphate will be performed.

9. Pre- and post-spill vandalism and erosion data will be compiled and evaluated to establish rates and effects of vandalism and erosion.

DISCUSSION

To assess the potential injury to historic properties along the coast, three physical zones can be established: submerged (below the lowest low tide), intertidal (between the lowest low and the highest high tides), and shore margin uplands (above the highest high tide). The greatest potential for damage exists through direct deposition of oil in the intertidal zone. Secondary transport into adjacent submerged areas and uplands may also injure historic properties. Upland historic properties are also subject to contamination from transportation of oil by wind, storm tide inundation, migration of contaminants in ground water, oiled bird and animal movement from the feeding/travel corridor of the intertidal zone, and their death and decomposition on archeological deposits. Theft of artifacts and vandalism to historic properties and archeological resources is a potential danger in the intertidal and upland zones. The intertidal zone contains historic properties of great variety, numbers, and susceptibility to oil damage. Shipwrecks, eroded/scattered artifacts, inundated stratified archeological deposits, prehistoric rock art, prehistoric fish weirs, and remnants of structures or objects deliberately placed in the intertidal zone are among the site types known to exist. The shore margin uplands may contain all the previously mentioned site types, plus burials, above-ground structures, and recognizable resource collection locations such as culturally modified trees.

In the two higher elevation zones, a major potential injury resulting from oil contamination is interference with traditional archeological dating techniques. Radiocarbon dating depends on comparison of the ratio of radioactive carbon 14 to carbon 12 in the sample being analyzed. Because petroleum contains abundant radioactively-inert carbon from organisms dead for millions of years, and the use of radiocarbon dating for dates up to 35,000 years ago, contamination by even a small amount of ancient carbon is expected to result in age determinations that are significantly older than the archeological event being dated. This would seriously compromise radiocarbon dating as a technique for dating human activities and paleoenvironmental events and conditions. The potential for affecting age determination may be significant even in areas where only a sheen exists and may be investigated in assessing injury. In cases of oil contamination in stratified archeological deposits, masking of the visibility and alteration of the chemical components of the microstratigraphy may also affect archaeologists' ability to trace strata.

Both direct and indirect injuries to historic properties may have occurred from response and treatment activities, as well as from increased activities in the resource areas. Further, increased access of personnel to remote areas may have increased the knowledge of site locations and potentially may accelerate vandalism, theft of heritage resources, and damage to the scientific value of the sites.

BUDGET: USFS

Personnel	$	382.0
Travel		12.0
Contracts		300.0
Equipment & Supplies		238.0
TOTAL	$	932.0

BUDGET:

Personnel	$	123.0
Travel		4.0
Contracts		96.0
Equipment & Supplies		77.0
TOTAL	$	300.00

TOTAL BOTH AGENCIES:	$	1,232.00

TECHNICAL SERVICES

The hydrocarbon analysis, histopathology, and mapping projects described in this section are designed to provide high quality technical services to studies described in other portions of the NRDA plan. Hydrocarbon analytical services includes the generation, archival, and retrieval of all chemical analytical data. Histopathology involves continuing the quality assurance program begun in 1989 and facilitating the analysis work of approved contractors employed by individual studies. Mapping includes implementing and managing a geographic information system to record and process data collected by NRDA studies.

Appropriate information on exposure of the resource to hydrocarbon residues from the spill is required to determine and quantify injury. It can be demonstrated by detailed information on the distribution and evolving chemical composition of the spilled oil through time, in concert with analyses of petroleum hydrocarbons or their metabolites in the tissues of organisms.

Samples of water, sediments and tissues for chemical analysis are being collected by individual studies throughout the entire region impacted by the EVOS. Selected samples are being analyzed by a team of participating laboratories in accord with a centralized QA/QC program (Appendix A) which will help ensure that all data are of known, defensible, and verifiable quality and comparability.

Information on the incidence of oil-induced histopathological conditions is required by many of the studies described under Fish/Shellfish, Birds, Marine Mammals, and Terrestrial Mammals. This information is being gathered under strict quality assurance guidelines (Appendix B) by a group of contracted histopathologists to ensure compatibility of results and evaluations throughout the NRDA program.

The mapping project will continue to develop the damage assessment geographic information system. Good progress has been made on the collection and verification of the primary data layers. Additionally, large scale production and transmittal of map products has begun.

TECHNICAL SERVICES STUDY NUMBER 1

Study Title: Hydrocarbon Analytical Support Services and Analysis of Distribution and Weathering of Spilled Oil

Lead Agency: USFWS, NOAA

INTRODUCTION

In order to document the exposure of resources in the PWS and GOA ecosystems to spilled oil, NRDA projects are collecting samples from a wide variety of environmental matrices to be analyzed for petroleum hydrocarbons. The data resulting from the analysis of these samples will not only be used to demonstrate an impact on that particular resource and support the individual project, but also to produce an integrated synthesis of the distribution of the oil in space and time, i.e., provide information on subsurface transport, residence time, and mass balance. Both of these uses require that the analytical data be accurate and precise, as well as of demonstrable quality. Analysis of the distribution of oil requires that the data be comparable from project to project through the entire NRDA process. The large number of samples and the length of time involved in the NRDA process require the use of more than one laboratory to provide analytical data. Rather than make each project responsible for analyzing their samples, TS 1 is responsible for analysis of all samples collected for hydrocarbon chemistry. This requires the generation, archival, and retrieval of all chemical analytical data.

To date, TS 1 has:

Developed and implemented an analytical chemistry QA/QC plan.

Developed and implemented a sample inventory and tracking system. This system forms part of the overall database management system for TS 1. Sample collection and quality data and analytical and associated QA/QC data are other parts of this system.

Contracted with the National Institute of Standards and Technology (NIST) to develop and supply calibration standards and control materials.

Initiated the measurement of petroleum hydrocarbons and their metabolites in water, sediment, tissues and bile. Some samples have already been analyzed and results comminuted to PIs. The remaining samples in the inventory have been assigned an analytical priority and will be released for analysis in that order.

Conducted a performance audit with participating analytical laboratories.

Initiated a synthesis of the distribution and composition of spilled oil with TS 3.

OBJECTIVES

A. Measure petroleum hydrocarbons, hydrocarbon metabolites and other appropriate chemical/biochemical measures of hydrocarbon exposure in water, sediment, and biota collected through the NRDA.

B. Prepare a QA/QC plan that establishes detailed procedures and protocols for sample collection, sample identification, chain of custody, and shipping.

C. Oversee and develop a centralized QA/QC program to assist the analytical laboratories in providing quality data and demonstrate the accuracy, precision, and comparability of all data developed by the program.

D. Provide technical on-site system audits of field and laboratory data collection activities.

E. Develop and provide appropriate instrument calibration standards and natural matrix control materials.

F. Develop an integrated synthesis of the distribution and chemical composition of spilled oil, as it weathers through time, to provide a detailed basis for final exposure assessment.

METHODS AND DATA ANALYSIS

Objectives A-E. This information is provided in "Analytical Chemistry QA/QC" (Appendix A).

Objective F. Data will be integrated and displayed by means of TS 3 mapping capability.

SCHEDULES AND PLANNING

Additional analytical support both in terms of number of laboratories and types of analyses, e.g. UV/F are being actively sought. At least one and perhaps two more facilities will be added to add analytical capability.

TS 1 will conduct a series of training sessions on the oil spill collection and handling of samples before the projects begin year two field work.

A proposal to transfer bar-coding sample-tracking technology will be considered.

Discussions on a sample holding time study have been initiated.

BUDGET: NOAA

Salaries	$	58.7
Travel		3.5
Contractual		832.5
Equipment		15.0
Supplies		4.5
Total	$	914.2

BUDGET: FWS

Salaries	$	62.0
Travel		5.2
Contractual		999.0
Equipment		7.0
Supplies		16.0
Total	$	1,089.2

TECHNICAL SERVICES STUDY NUMBER 2

Study Title:	Histopathology: Examination of Abnormalities in Tissues from Bird, Mammals, Finfish, and Shellfish Exposed to the Spilled Oil
Lead Agency:	ADF&G

INTRODUCTION

Histopathology is an important tool used in determining mechanisms of death and sublethal effects caused by infectious agents and toxic substances. A number of histopathological conditions are known to result from exposure to oil. Evidence of these conditions will be documented in tissue samples taken by individual NRDA studies as one means of demonstrating spill-related injury. Histopathology technical services will support that effort by continuing the quality assurance program begun in 1989 and by facilitating analyses by approved contractors.

OBJECTIVE

Measure the incidence of histopathological conditions and external lesions in selected species of birds, mammals, finfish, and shellfish collected by NRDA studies.

METHODS

Standard histological methods for collection, preservation, processing, and interpretation, as specified in the quality assurance program (Appendix B), will be continued. Assistance will be provided to NRDA studies in selecting and contracting with labs or individuals to complete analyses.

BUDGET: ADFG

Salaries	$ 20.0
Travel	5.0
Contracts	70.0
Supplies	5.0
Equipment	0.0
Total	$100.0

TECHNICAL SERVICES STUDY NUMBER 3

Study Title: Implement and Manage a Geographic Information System (GIS) to Record and Process NRDA Data

Lead Agency: DNR and FWS

Cooperating Agency: USFS and DEC

INTRODUCTION

The purpose of Technical Services Number 3 (TS3) remains unchanged: the group is charged with implementing and managing the geographic information system (GIS) to record and process data collected in NRDA studies. Good progress has been made on the collection and verification of the primary data layers. Additionally, TS3 has begun large scale production and transmittal of NRDA map products.

OBJECTIVES

1. Produce and disseminate requisite maps and analytical products for participants in the natural resource damage assessment process.

2. Create and maintain, throughout the damage assessment process, a data base or data pertinent to the overall damage assessment process, in a way that is accessible to all of the participating agencies.

METHODS

Methods are essentially the same as described in the 1989 study plan. In addition to the data layers described in the 1989 study plan, data layers have been or will be prepared for study site locations, sampling locations, beach segment locations and multi-thematic atlases of pre-spill data from various sources. Additional data layers will be added as needed by investigators and the Trustee Council to enable geographic-based compilation of study results and other pertinent data.

Quality control will continue to be emphasized, with review of information in data layers against qualified data sources and full documentation of source data and review procedures. A data backup system which includes redundant backup and off-site storage has been implemented and will be maintained.

BUDGET: DNR

Salaries	$	332.4
Travel		11.2
Contracts		69.6
Supplies		67.0
Equipment		112.0
Total	$	592.2

BUDGET: FWS

All Activities	$	200.0
Total	$	792.2

PART II

ECONOMICS

ECONOMIC STUDIES

The studies in this section are federal studies designed to assess the economic value of injury to natural resources associated with the EVOS. State studies designed to assess the economic value of injury to natural resources resulting from the EVOS are not discussed in this document.

The federal studies cover seven major areas: (1) commercial fishing, (2) public land values, (3) recreation, (4) subsistence, (5) intrinsic values, (6) research programs and (7) archaeological resources.

ECONOMICS STUDY NUMBER 1

Study Title: Commercial Fisheries Losses Caused by the EVOS

INTRODUCTION

This study combines the studies previously designated as Economics Study Number 1 (Estimated Price Effects on Commercial Fisheries), Economics Study Number 2 (Fishing Industry Costs) and Economics Study Number 3 (Bioeconomic Models for Damage Assessment) with primary emphasis on former Economics Study Number 1.

The EVOS may have resulted in substantially reduced seafood production at, among others, Cordova, Seward, Kodiak, Kenai, and Homer, which are some of the most important commercial fishing ports in the United States. Both short term impacts, through closure of certain fisheries, and long term effects, such as reductions in population that will not become apparent for several years as well as through continued exposure to contaminants, may occur. These impacts may affect both the supply of and demand for seafood.

For example, changes in quality (both real and perceived) may have occurred, which could adversely affect seafood markets. In the case of several important commercial salmon fisheries, the spill resulted in harvests being confined to "terminal" areas, thus restricting traditional fishing patterns and timing of the harvest.

Terminal area harvests occur in close proximity to the salmon's spawning grounds. The result can be a significant reduction in quality, as compared to salmon harvested in more typical circumstance, i.e., more distant from, but en route to, spawning sites. The reduction in quality may affect the salmon's overall marketability and/or its appropriateness and acceptability for specific product forms. In either case, seafood consumers at every market level incur losses.

Salmon is only one commercial species group which may have been adversely affected. Others may include Pacific halibut, Pacific herring, sablefish, shellfish and groundfish.

OBJECTIVES

Measure the economic loss to seafood consumers caused by the EVOS.

METHODS

The species most affected by the spill must first be determined. Conceptual models of consumer preferences and market characteristics for certain seafood products must be created. Furthermore, a methodology to assess statistically changes in the level and quality of harvest must also be established. Next, the data appropriate for the models must be collected, assembled and assessed. The models will then be used to estimate the demand for various seafood products, the price changes associated with the spill, and the effects of seafood quality and quantity changes on consumers.

BUDGET

Salaries	$ 103.0
Travel	15.0
Contracts	95.0
Supplies	7.0
Equipment	9.0
Total	$ 229.0

ECONOMICS STUDY NUMBER 4

Study Title: Effects of the EVOS on the Value of Public Land

INTRODUCTION

The EVOS affected subtidal, intertidal, tidal and uplands areas on the shores of PWS and the GOA. This study will assess the lost market value of publicly held lands attributable to the oil spill. It will estimate market demand for leases and sales of land in the impacted areas, and project changes in total value of public lands.

OBJECTIVES

Determine the change in market values of public lands.

METHODS

Land appraisals are a common method of assessing the market value of land. Appraisers usually estimate the market value of land parcels from the selling price of similar parcels. Because no two parcels are identical, adjustments are required to achieve comparability. For the purposes of appraisal, market value is generally defined as the amount in cash, or in terms reasonably equivalent to cash, for which, in all probability, the property would be sold by a knowledgeable owner who is willing but not obligated to sell to a knowledgeable purchaser, who desires the property but is not obligated to buy. Using this definition of market value, the effect of the oil spill on land values will be estimated as the difference between the pre- and post- spill selling prices.

This study will proceed in several stages. First, a conceptual model will be developed to determine the total public value of a land parcel and to show how land appraisals fit within that model. Next, an attempt will be made to identify instances where land value studies can provide estimates of value changes that are not captured by other economic studies. Third, the adequacy of appraisals as a method of assessing changes in land values due to the spill will be evaluated.

If appraisals are warranted, they will be conducted by obtaining data on ownership patterns in areas affected by the oil spill, gathering data on previous oil spills and their effect on land values, estimating the effect of the oil spill on the value of property through use of paired-scale data, and inspecting areas affected by the oil spill.

BUDGET

Salaries	$ 96.0
Travel	20.0
Contracts	50.0
Supplies	5.0
Equipment	9.0
Total	$180.0

ECONOMICS STUDY NUMBER 5

Study Title: Economic Damages to Recreation

INTRODUCTION

The EVOS has impacted natural resources that support a wide range of recreational activities including fishing, hunting, boating, hiking, camping, and sightseeing. Because of their unique attributes, these resources attract recreationists from throughout the United States and other countries to PWS and the GOA coast.

The oil spill may result in economic damage to those resources' recreational services in two principal ways: 1) some recreationists who otherwise would have gone to the area will choose a substitute activity and/or area, thereby potentially suffering a loss in personal satisfaction and possibly incurring increased costs, and 2) recreationists who visit the area may suffer reduced satisfaction because of the oil spill's adverse impacts on recreational services that the natural resources otherwise would have provided. These types of losses may have been experienced by sea kayakers, users of charterboat services, recreational fishers, cruise ship patrons and general tourists.

While relatively few in number, sea kayakers may have been significantly affected by the oil spill. Kayaking trips are taken from Valdez, Kodiak, Homer, Whittier and Seward to the western portion of PWS and the bays along the Kenai peninsula and Kodiak Island. A typical trip involves charter boat transportation to a site some distance from port. Most trips last more than one day and thus include both kayaking and wilderness camping. Southcentral Alaska includes some of the premier kayaking areas in the world.

The potential effect of the oil spill on kayakers could take several forms:

- beaches used for wilderness camping are oiled and unusable;
- wilderness scenery is despoiled and sense of pristine environment is lost;
- wildlife viewing opportunities are reduced;
- areas un-oiled suffer from increased congestion;
- clean-up activities make boats for transport expensive or impossible to charter; and
- clean-up activities spoil the wilderness nature of the experience.

All of these potential effects may have applied during the 1989 season; some may remain for several years.

Recreational activities that use the services of charterboats and other private boats for hire are typically less intense than sea kayaking, but they are far more numerous. Vessels for hire and charterboats range from the standard six passenger charterboat called a "sixpack" to large tour boats carrying over a hundred passengers. All types of vessels for hire have been impacted by cleanup activity. For brevity in this proposal, this entire group is referred to as "charterboats." Charterboat related recreational activities include salmon and halibut fishing, sightseeing and viewing marine wildlife and ferrying for wilderness camping in the PWS, KP and Kodiak areas. Charterboats go out of Valdez, Whittier, Homer, Kodiak, Seward and the smaller villages in southcentral Alaska.

Because access to the general area is not easy, there are potentially substantial impacts which can be measured through a careful study of the charter fleet. The purpose of such a study would be to determine the reduction in the use of the PWS environment through the charter fleet as a consequence of the oil spill.

The level of participation in recreational fishing among the residents of Alaska is far greater than among the residents of any other state in the United States. Marine recreational fishing originates in all major towns on the PWS as well as Cook Inlet, Kodiak Island and the KP and the Alaska Peninsula. Fishing trips are taken in several ways -- from shore, from private boats and from charter vessels. Because access by car from Anchorage is relatively easy, shore fishing and private boat fishing on the Kenai is quite popular. All kinds of fishing draw large numbers of tourists to Alaska.

The previous study of charterboats will address only part of the potential recreational fishing effects. It is possible that the oil spill had detrimental effects on shore and private boat recreational fishing, as well. For example,

a) fishing trips in the potentially oiled areas may have declined due to fear of contaminated fish and waters;
b) anglers may not have been able to find accommodations in areas where they wanted to fish because of cleanup related activities.
c) the value of particular fishing trips out of the potentially oiled zones may have declined because sites became more congested.

Each season, a number of cruise ships pass through PWS on their way from Seattle or Juneau to Whittier where they discharge their passengers for the train trip to Anchorage. The likelihood that these individuals were directly affected by the oil spill is small, but many have canceled their trips because of fear that the oil spill would spoil the experience.

The general tourist activity sub-component of the proposal differs from the others in that it is not directed toward one specific recreational activity. Here the goal is to determine, from aggregate level data, the extent to which general tourist activity in the area of the spill may have been dislocated because of clean-up activities. There will have been losses to recreationists if these activities were diverted away from areas thought to be contaminated by the spill or affected by the congestion and lost services associated with clean up. Some of the marine related part of this damage will be captured in the investigation of the charterboats and kayaking. However, those people who do not plan to use boats but rather state parks or other facilities will not have been covered.

OBJECTIVES

Develop estimates of economic injuries to recreationists.

METHODS

The study will look at the types of consumptive and nonconsumptive recreational activities.

Sea kayaking: This study contains several stages. First, the relevant sea kayaking population will be identified. Second, a survey instrument which will contribute to both recreational demand and simple contingent valuation analysis will be created. Third, the survey instrument will be pretested. Fourth, the survey will be administered. Fifth, the survey results will be analyzed.

Charterboat activities: Data for this study will also be collected through a survey instrument. After development of a theoretical framework for damage measurement, the sample frame will be defined. A survey instrument will be designed to determine the periodic recreational and cleanup activities undertaken by each charter vessel, the number of recreationists served, the extent of cancellations and the amount of time the vessel was involved in clean up activity. Vessel owners may also be interviewed in person. Finally, the data will be analyzed.

Recreational fishing: There is an existing model for recreational fishing in the KP area. This model will be investigated to determine whether it can be usefully applied to the effects of this oil spill.

Cruise ship tours: Cruise ship firms will be contacted to determine whether demand for cruise ship tours to PWS were affected by the oil spill. If there is evidence of substantial reductions in demand, methods of estimating the actual losses to recreationists will be explored.

General tourist activity: Assuming that aggregate effects on tourism may be accurately estimated, this study will compare those aggregate effects with the results of the activity directed substudies to determine whether important categories of losses have been missed.

BUDGET

Salaries	$ 229.0
Travel	27.0
Contracts	20.0
Supplies	8.0
Equipment	10.0
Total	$ 294.0

ECONOMICS STUDY NUMBER 6

Study Title: Losses to Subsistence Households

INTRODUCTION

Several communities on the shores of PWS, LCI, Kodiak Island, and the Alaska Peninsula, and in or near the EVOS area, are highly dependent upon noncommercial fishing, intertidal food gathering, marine mammal hunting, and land mammal hunting for subsistence uses. Among the small subsistence communities are Tatitlek, Chenega Bay, English Bay, Port Graham, Ouzinkie, Port Lions, Larsen Bay, Karluk, Akhiok, Old Harbor, and Chignik Bay. Larger subsistence communities include Cordova, Valdez, Seldovia, and Kodiak. Subsistence uses are defined as rural Alaska residents' customary and traditional uses of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of nonedible byproducts of fish and wildlife resources taken for personal or family consumption; for barter, or sharing for personal or family consumption; and for customary trade. Those uses are designated as the priority public consumptive use of wild resources.

Following the oil spill, subsistence harvests were reduced in several communities because of health concerns. This could have important ramifications in the economy and social order of the communities. Potentially important economic losses to the communities include (1) subsistence losses, (2) local inflation affecting harvests and food procurement, (3) damage to subsistence property and (4) loss of intrinsic value to subsistence users.

OBJECTIVES

A. Conduct a literature review and compile base line information.

B. Document extent of oil contact and clean-up on or near historic harvest sites.

C. Document changes in subsistence use through time (i.e., species selection; harvest timing, quantities, areas, methods, and efficiency; and household participation rates in harvest, use, sharing, barter, and exchange).

D. Document local social and economic changes that affect subsistence use, including wage/labor patterns, income levels, inflation rates in the villages for goods and services, cleanup work, outside agency demands, and industry demands.

E. Assign monetary values to losses to subsistence households.

METHODS

Field observations and interviews will be used to collect information. Changes in subsistence use and socioeconomic patterns will be determined by conducting systematic household surveys and interviews, and comparing these data to historic information. Where applicable market prices and price imputation will be used to estimate damages. For marketed goods, the cost of replacing the goods injured by the spill will normally be the measure of economic damage. However, the adverse effects of the spill extended beyond marketed goods. To determine the economic damages to non market goods and services, survey methodologies, similar to those described in Study 7, will be employed.

BUDGET

Salaries	$ 255.5
Travel	48.0
Contracts	237.5
Supplies	151.4
Equipment	192.6
Total	$ 885.0

ECONOMICS STUDY NUMBER 7

Study Title: Loss of Intrinsic Values Due to the EVOS

INTRODUCTION

Intrinsic values include existence value, option value, and bequest value. These values are independent of the economic values arising from direct use of natural resources and cannot be measured by observing use of the area affected by the EVOS. Resources with intrinsic values include fish, birds and mammals, along with the wilderness character, ecological integrity and/or scenic quality of certain areas. These values are only imperfectly captured by the prices of goods traded in markets. Accordingly, non-market methods must be used to calculate intrinsic values. This study is designed to use the contingent valuation method to determine the loss in intrinsic values resulting from the oil spill.

OBJECTIVES

Determine the loss of intrinsic value of natural resources attributable to the EVOS.

METHODS

The contingent valuation method involves use of surveys to determine the values that people place on goods that are not traded in markets. This study will require development of a conceptual framework for contingent valuation survey design and analysis of survey results. Next, research will be conducted to determine the most accurate survey instrument for assessing intrinsic values. This research will involve consultation with economists and survey design experts. Substantial preliminary testing of survey formats will be conducted among small groups of people to verify the accuracy of the survey instrument. A nationwide survey will be conducted using a professional survey research firm. Econometric analysis will be used to interpret the results of the survey.

BUDGET

Salaries	$ 515.0
Travel	145.0
Contracts	680.0
Supplies	295.0
Equipment	375.0
Total	$2,010.0

ECONOMICS STUDY NUMBER 8

Study Title: Economic Damage Assessment of Research Programs Affected by the EVOS

INTRODUCTION

The oil spill affected research programs in the vicinity of the spill, resulting in damage to or loss of various research and resource monitoring studies. Opportunities to study natural resource systems in the affected area may have been lost or diminished as a result of the spill. Research studies underway before the spill and conducted, permitted, cooperatively participated in, sponsored or funded by the federal government likely were impacted. One example is a study involving tagging of fish that was in progress in an affected area of PWS. Determination of the set of studies affected and the extent or degree of damage will require careful evaluation and study.

OBJECTIVES

Assess damage to and economic loss of research investigations, and account for the cost of resources expended in affected studies, focusing on research-based expenditures made or committed to before the oil spill.

METHODS

The first step in this study is to identify the universe of studies that were underway in the affected area at the time of the spill. The next stage requires a determination of which studies were negatively impacted by the spill. Some of those impacts may have been so significant that the entire study was discontinued. Other studies may have been able to continue, but only at an increased cost caused by the impacts of the spill. For example, sample sets may have been destroyed or the study may have been moved to another area. Once the universe of affected research programs is identified, this study will value the destroyed and damaged research studies by looking first to total project costs, extra sums expended and amounts spent on each study prior to being impacted by the spill.

BUDGET

Salaries	$ 23.5
Travel	10.0
Contracts	10.0
Supplies	7.5
Equipment	0.0
Total	$ 51.0

ECONOMICS STUDY NUMBER 9

Study Title: Quantification of Damage to Archeological Resources

INTRODUCTION

Archeological sites along the many miles of oiled coastline and intertidal zones may have been physically damaged by oil. Upland sites may have been damaged by erosion caused by destruction of site vegetation or transportation of the oil inland. Loss to archeological resources includes direct and indirect oiling. Determination of the number of cultural resources impacted by the oil spill as well as the type and extent of injury to the archeological sites has been moved to a separate science study. The economics study is now limited to quantifying the loss to archeological resources.

OBJECTIVES

Assess the economic damages to archeological sites.

METHODS

The archeological science study will create a data base containing listings of the oil impacted areas and a model for the kinds of cultural resources impacted, the degree of the impact and the physical setting of the damaged resource. Both use and intrinsic values of archeological resources may have been impacted.

Use Value

1. Effects on the scientific value of the archeological resource. The magnitude of this damage depends on the uniqueness of the affected site, the original quality of information available at the site, the nature of the impacts, and the willingness of the scientific community to pay for the lost information. If the site is unique and substitute sources of similar information do not exist, the value of the damage may be large.

2. Loss of value as tourist and educational attractions. Unique or spectacular archeological sites have value as tourist attractions. All significant archeological sites have educational value as the focus of field trips and published descriptions. Archeological information and artifacts have value for museum interpretation and display. Oil impacts could substantially reduce these values.

Intrinsic Value

1. Impacts on the religious, cultural or symbolic values for native groups.

2. Loss of intrinsic value for the general, non-native population.

BUDGET

Salaries	$ 25.0
Travel	15.0
Contracts	0.0
Supplies	10.0
Equipment	0.0
Total	$ 50.0

PART III

RESTORATION PLANNING

RESTORATION PLANNING PROJECT

INTRODUCTION

The Trustees recognized from the beginning that restoration of the ecological health of areas affected by the oil spill is the fundamental purpose for conducting the NRDA. Initially, studies to determine the injury to natural resources were emphasized, since that information is basic to a determination of damages, and finally, restoration of resources.

Since late 1989, considerable effort has gone into specific restoration planning activities. An interagency Restoration Planning Work Group (RPWG) was formed to develop and coordinate what is envisioned to be a steadily growing level of activity throughout this year and next. A variety of activities have already been initiated by the RPWG and several more are proposed to occur during 1990, as described in the following pages. In addition, it is anticipated that restoration planning and project activities will be expanded further in 1991 and beyond.

OBJECTIVES

The overall goal of the Restoration Planning Project is to identify appropriate measures that can be taken to restore the ecological health of natural resources affected by the EVOS. Among the objectives within this overall goal are:

A. Encourage and provide for public participation and review during the restoration planning process.

B. Identify and develop technically feasible restoration options for natural resources and services potentially affected by the oil spill.

C. Incorporate an "ecosystem approach" to restoration (i.e., broadly focus on recovery of the ecosystems, as well as individual components).

D. Identify when active restoration measures may be warranted, and when it may be appropriate to rely on natural recovery.

E. Identify the costs associated with implementing feasible restoration measures, in support of the overall NRDA process.

DEFINITION

Restoration is a broad term that can include direct restoration, replacement, or acquisition of resources or uses those resources provided that are equivalent in terms of ecological or human services.

Direct restoration refers to measures taken to restore an injured resource, and generally equates with on-site actions. An example would be to rehabilitate an oiled marsh ecosystem by supplementing natural plant and animal populations after removal of the oil.

Replacement refers to the substitution of one resource for an injured resource of the same type. An example is to use hatchery/aquaculture techniques to establish an entirely new fishery stock in place of one that has been severely damaged. Replacement activities may or may not be limited to the specific site or area where injury occurred.

Acquisition of equivalent resources means to obtain or otherwise protect resources that are similar or related to the injured resources in terms of ecological value, functions, or uses. An example is to obtain or protect undamaged wildlife habitats as alternatives to direct restoration of injured habitats. Equivalent resources could be acquired in locations removed from the immediate vicinity of the injured resource.

1990 RESTORATION PLANNING ACTIVITIES

Several major activities have been initiated or are proposed under the Restoration Planning Project in 1990. Each major activity area is described in this section.

Public Participation

In part as a response to public comments on the 1989 NRDA Plan, several avenues have been developed for public involvement in the restoration planning process. The RPWG has conducted a public Restoration Symposium, and held public information and scoping meetings in several Alaskan communities directly affected by the oil spill. Additional public meetings may be held outside Alaska during 1990 as well. The RPWG has also begun to contact interest groups and other organizations that have expressed an interest in the restoration planning process, in order to gain a more direct and detailed understanding of their concerns and suggestions. An information flier and response form has been developed and distributed initially in Alaskan communities in order to encourage additional comments from residents of areas most directly affected by the spill. Reports generated through the Restoration Planning Project will generally be distributed publicly. The following paragraphs briefly describe the outcomes of the major public activities conducted to date.

Restoration Symposium

A two-day public Restoration Symposium was held at the Egan Civic and Convention Center in Anchorage, Alaska on March 25 and 26, 1990. The symposium was the first opportunity for environmental, industry, and other interest groups and members of the general public to present their views about the content of a restoration plan. Formal presentations were made by more than 30 individuals. A report documenting the presentations and comments given at the Restoration Symposium is scheduled to be publicly distributed in July 1990.

Community Scoping Meetings

An initial series of public information and scoping meetings was held beginning in April 1990. The RPWG travelled to eight Alaskan communities directly affected by the oil spill to provide an opportunity for residents to express their views about what a restoration plan should entail. Evening meetings were held in Cordova, Valdez, Whittier, Seward, Kenai, Homer, Kodiak and Anchorage. The community scoping meetings resulted in a variety of restoration ideas being identified. Public comments received as a result of the community scoping meetings will be documented in the progress report scheduled for public distribution in July 1990.

Technical Workshops on Restoration

The RPWG conducted an initial three-day technical workshop on restoration in Anchorage in early April, 1990. The workshop provided a forum for the scientists most familiar with the effects of the oil spill, as well as other scientists with relevant knowledge, to focus their attention on potential restoration needs and opportunities. A second technical workshop is planned for the Fall 1990, and it is anticipated that more such opportunities will occur before the conclusion of the process. One purpose of the first technical workshop was to help identify and develop an initial set of potentially beneficial restoration techniques that could receive small-scale field testing during the Summer 1990. An array of potential feasibility study projects was identified, some of which are proposed to be initiated (see Restoration Feasibility Studies below). The results of the workshop will be documented in the progress report scheduled for public distribution in July 1990.

Literature Review

The first phase of a comprehensive search of worldwide literature relevant to restoration of natural resources was initiated early in 1990. "Phase I," the initial search of key computerized literature data bases, identified several thousand potentially relevant references, which were narrowed to approximately one thousand of the most directly applicable citations. These references have been screened, and the most important ones have been flagged for acquisition. These references will be reviewed in detail during the "Phase II" literature review, along with other references identified in an expanded search. Literature review activities are expected to continue throughout the restoration planning process. The results of "Phase I" will be summarized in the progress report scheduled for public distribution in July 1990. Updated results will be presented in subsequent reports.

Feasibility Study Projects

There are relatively few existing technologies for restoration of natural resources that can be immediately applied under Alaskan conditions with certainty of success. For this reason, feasibility study projects are among the most important aspects of restoration planning. A feasibility study project may be appropriate when a restoration idea has been developed that appears to be potentially beneficial, but for which there is substantial uncertainty of its success or benefit with local species or under the sub-arctic conditions of the spill area.

The following pages present summaries for each of the initial feasibility study projects proposed for 1990. These projects were developed from ideas presented at the public symposium, the community scoping meetings, and the technical workshop. Factors considered in selecting 1990 studies included: the need to initiate the particular study as soon as possible, the ability to implement the project in a short time frame, reasonable likelihood of success, identified public concern, relationship to other NRDA studies, and budget priorities.

Five restoration Feasibility Studies having a total budget of $326,400 are proposed for initial field testing in 1990. Two of these concern restoration of intertidal resources and communities, one addresses upland habitats used by wildlife affected by the spill, one involves stabilization and restoration in the supratidal zone, and one supports the potential acquisition of equivalent resources through review of land status, uses, and plans.

Three restoration technical support projects with a budget of $236,500 are planned. The first will institute a formal peer review process for restoration project results and planning. The second will compile shoreline status information from both response and NRDA sources to support selection of sites and habitats for future feasibility studies and restoration projects. The third technical support project will fund development of detailed proposals for feasibility studies to be considered for implementation in 1991.

BUDGET

Restoration symposium	$ 50.0
Community scoping meetings	40.0
Technical workshops	200.0
Literature collection/review	90.0
Feasibility study projects	562.9
Report preparation/publication	150.0
Salaries	600.0
Travel	70.0
TOTAL	$1,762.9

Lead agencies: EPA, ADF&G

Cooperating Agencies: DNR, DEC, DOA, DOI, DOC

RESTORATION TECHNICAL SUPPORT PROJECT NUMBER 1

Project Title: Peer Reviewer Process for Restoration Feasibility Studies

Lead Agency: RPWG

Cooperating Agencies: DOJ, DOL

INTRODUCTION

The initial feasibility study projects to be conducted during the 1990 field season were developed with the assistance of many of the scientists involved in the NRDA process, after considering comments received at the technical workshop and a series of public meetings held in Spring 1990 in Alaska. Due to the limited time available before projects need to be in the field, an additional more formal round of peer review is not possible. This technical support project is designed to incorporate formal peer review in the design, implementation, and evaluation of 1991 and future feasibility studies. It will also provide for detailed review of 1990 feasibility study results.

OBJECTIVE

Implement a peer reviewer process to assure the scientific quality of feasibility studies and restoration projects.

METHODS

Peer reviewers may include experts already involved in the NRDA process, experts involved in the technical workshops on restoration, or other selected individuals. Peer reviewers would review and comment on feasibility study proposals (including overall design and detailed study plans) and results. The budget for 1990 is based on the services of 10 expert reviewers for five days each, plus expenses. It is anticipated that this technical support project will expand in 1991, as additional feasibility studies are initiated and as results from 1990 feasibility study projects become available.

BUDGET: DOJ, DOL

Salaries:	$ 0.0
Travel:	0.0
Contractual Services:	70.0
Supplies:	5.0
Equipment:	0.0
TOTAL:	$75.0

RESTORATION TECHNICAL SUPPORT PROJECT NUMBER 2

Project Title: Assessment of Beach Segment Survey Data

Lead Agency: DNR

Cooperating Agencies: DEC, ADF&G, USFS, NPS, EPA

INTRODUCTION

There is a large volume of beach-survey information obtained through response activities (e.g., the fall and spring surveys) and NRDA studies (e.g., CH 1). All of these data are being integrated into a standard NRDA data base. This information is being reviewed and summarized with respect to restoration planning needs and will complement and support Restoration Feasibility Study Number 5 (RF 5). Together, this information will help identify potential sites at which (a) hands-on restoration projects may be carried out, and (b) equivalent resources may be acquired. Additionally, it should prove valuable in providing further information for analytical purposes in the development of the restoration planning matrix.

OBJECTIVES

A. Obtain and translate to maps, pertinent beach survey information that is important for feasibility studies and restoration projects.

B. Analyze possible trends in information for applicability to restoration feasibility studies.

C. Create a data base for future reference use in restoration projects.

Relationships with Other Studies:

This project relates directly to RF 5 and provides data of fundamental importance to the entire Restoration Planning Project.

METHODS

Research and map, using standard cartographic and G.I.S. techniques, all available information from the Fall 1989, Spring 1990, and Fall 1990 walk-a-thon and shoreline assessment team surveys. Combined with RF 5, this will provide further support in the selection process for specific restoration sites and habitats. It may also prove advantageous for documenting natural recovery processes that may be occurring. Care will be taken to not duplicate existing data bases and maps. The need is to integrate new information and summarize it in a form helpful to the Restoration Planning Project. This project will essentially add a "restoration layer" to the existing NRDA data base.

BUDGET: DNR

Salaries	$ 16.0
Travel	0.0
Contractual Services	5.0
Supplies	4.0
Equipment	0.0
TOTAL	25.0

RESTORATION TECHNICAL SUPPORT PROJECT NUMBER 3

Project Title: Development of Potential Feasibility Studies for 1991

Lead Agency: ADF&G and EPA

Cooperating Agencies: DNR, DEC, DOA, DOI, DOC

INTRODUCTION

A variety of potential restoration feasibility studies need to be undertaken before recommendations can be made in the Restoration Plan. Due to funding and timing constraints in 1990, it was possible to carry out only a limited number of such studies in the current season. There is much that can and needs to be done, however, to develop the substance of feasibility study proposals for possible implementation in 1991. A number of specific areas have been identified for development of study plans. These include (A) Monitoring "Natural" Recoveries, (B) Pink Salmon Stock Identification, (C) Herring Stock Identification/Spawning Site Inventory, (D) Artificial Reefs for Fish and Shellfish, (E) Alternative Recreation Sites and Facilities, (F) Historic Sites and Artifacts, and (G) Availability of Forage Fish. In addition, as new information becomes available through the NRDA process, public comments, and technical consultations, the RPWG expects to identify additional restoration ideas and areas of concern for which feasibility studies may be appropriate.

Objectives:

A. To identify restoration ideas and areas of concern for which feasibility studies may be necessary and appropriate.

B. To develop feasibility study plans and proposals which may be considered for implementation in 1991 and beyond.

Relationships with Other Studies:

This project relates directly to Restoration Technical Services Project Number 1, implementation of a peer reviewer process, as well as the entire NRDA and Restoration Planning Project.

Methods:

Based on public comments, NRDA results, and consultations with technical experts, the RPWG anticipates that candidate restoration projects will be identified on an on-going basis. In order to fully evaluate some of these suggestions, it will be necessary to carry out feasibility studies. The RPWG then needs to convene ad hoc committees consisting of combinations of agency personnel, peer reviewers, and outside experts to more fully develop the study plans and proposals. Support is needed to convene meetings, particularly involving travel by outside experts. In some cases, site visits will be needed to examine particular problem areas related to the oil spill or successful restoration projects which have been implemented elsewhere.

BUDGET:

Salaries	$ 5.0
Travel	77.5
Contractual Services	40.0
Supplies	11.0
Equipment	3.0
TOTAL	136.5

RESTORATION FEASIBILITY STUDY NUMBER 1

Study Title: Re-establishment of Fucus in Rocky Intertidal Ecosystems

Lead Agency: EPA

Cooperating Agency: USFS

INTRODUCTION

Qualitative evidence indicates that rockweed, the marine alga, Fucus, was damaged by both the spilled oil and the cleanup effort. Fucus is a critical structural component of the intertidal habitat in the oil-spill area, and it serves as an important spawning substrate for herring. Re-establishment of this species will increase the rate of recovery of other associated biotic communities.

There may be a substantial delay in natural recovery of areas where populations were reduced over large areas (100-1000 m of shoreline), because dispersal of seeds is limited (< 1 m in most circumstances). Drift plants may increase this distance, but the importance of this mode is unknown.

The reproductive and life history of Fucus is well known, and techniques for collection of seed are well established. In southern parts of the range plants are fertile year round, so the timing of the application of seeds may be relatively unimportant in the establishment of the plant. The specific life history cycle of the plant in PWS and the GOA is not known. It is expected, however, that the plants will be fertile for at least most of the spring and summer.

Objectives:

A. Document the extent and magnitude of recruitment of Fucus in areas subjected to alternative cleaning technologies.

B. Determine the feasibility of re-establishing Fucus in damaged areas.

C. Develop and demonstrate potential large scale seeding techniques to re-establish Fucus.

D. Demonstrate the efficacy of seeding versus transplanting Fucus.

E. Identify the costs of implementing a full-scale Fucus restoration project.

Relationships with Other Studies:

This study is fundamental to bringing an ecosystem approach to the restoration program. It relates directly to RF 2, re-establishing critical intertidal fauna, and to various NRDA studies, particularly Coastal Habitat Study Number 1.

Methods

The study plan has two parts: (1) laboratory experiments that develop techniques for obtaining large quantities of embryos suitable for use in reseeding, and (2) field experiments to test the effectiveness of embryo reseeding and transplanting in habitats that experienced varying degrees of oiling and cleaning.

Laboratory experiments will be conducted to determine embryo attachment strength over time. Since the seeds must remain in suspension, experiments will also be conducted to assure their viability in culture media for at least two weeks. Although techniques for obtaining Fucus embryos are simple and well known, these techniques will be modified and tested for the production and handling of the large numbers of embryos that would be necessary for a full-scale reseeding project.

Field tests will then be conducted with various "seeding" procedures (e.g., dispersal of embryos, dispersal of embryos, and transplants of fertile adults). All three methods will be tested in one control and one habitat that was disturbed by oil and subsequently cleaned. Dispersal of embryos will then be tested in habitats with different combinations of oil and cleanup techniques (e.g., bioremediated, hot water wash). The experimental design will use three replicates of each habitat type, three replicates of each procedure, and three replicates of controls to measure natural settlement. Variables to be measured include height of Fucus plants, numbers of plants, and percent vegetative cover. Maps prepared by the Damage Assessment Geoprocessing Group will be used to identify potential study sites. In the initial project, primary study sites will be in or near Herring Bay, PWS.

BUDGET: EPA

Salaries	$ 2.0
Travel	11.0
Contractual Services	135.0
Supplies	2.0
Equipment	0.0
TOTAL	150.0

RESTORATION FEASIBILITY STUDY NUMBER 2

Study Title: Re-establishment of Critical Fauna in Rocky Intertidal Ecosystems

Lead Agency: USFS

Cooperating Agency: EPA

INTRODUCTION

Intertidal ecosystems on rocky shores, including both fauna and flora, were seriously affected by the oil spill and cleanup activities. Initial results suggest that certain key faunal species, such as grazers and predators, that are likely to structure these intertidal communities, were moderately to heavily affected. Natural restoration processes in these communities will be limited by recolonization rates of these key species, which in some cases are known to be quite low. Re-establishment of *Fucus* alone may therefore not be sufficient to ensure a return to pre-spill conditions on ecologically meaningful time scales. Before a restoration plan is proposed, we should demonstrate the feasibility of enhancing the rate of recovery of the intertidal community by the re-establishment of key grazers and predators. If the natural recoveries of *Fucus* and intertidal fauna can be augmented by restoration projects, it will be of fundamental benefit to the marine ecosystem.

OBJECTIVES

A. Compare rates of recovery of rocky intertidal communities with and without key faunal species and combinations of species.

B. Demonstrate the feasibility of restoring rocky intertidal communities by enhancing colonization by key faunal species.

C. Determine the costs of implementing a full-scale restoration project to re-establish key faunal species in rocky intertidal ecosystems.

Relationships with Other Studies:

This study will be carried out in conjunction with the *Fucus* study, R/F 1, and it is related to several other NRDA studies, particularly CH 1.

METHODS

Based on results of NRDA studies, limpets have been identified as important grazers that were harmed by the oil spill in rocky intertidal ecosystems. Predators, such as *Nucella* and *Leptasterius*, also could be important in structuring these intertidal communities. Rates of recovery of intertidal areas with and without key species and combinations of species will be compared. Grazer, predator, and grazer-predator exclusion and enhancement plots will be established in habitats that experienced differing degrees of oiling or were subjected to different cleanup techniques (e.g., bioremediated, hot-water high-pressure cleaned). A key aspect of the study will be demonstrating the feasibility of enhancing colonization by key species.

BUDGET: USFS

Salaries	$ 0.0
Travel	5.0
Contractual Services	65.0
Supplies	2.0
Equipment	3.0
TOTAL	75.0

RESTORATION FEASIBILITY STUDY NUMBER 3

Study Title: Identification of Potential Sites for Stabilization and Restoration with Beach Wildrye

Lead Agency: DNR

Cooperating Agencies: USFS

INTRODUCTION

The EVOS and associated cleanup efforts have affected supratidal beach ecosystems, of which a key component is the native grass, beach wildrye (*Elymus mollis*). The supratidal beach wildrye plant community is extremely important in the prevention of erosion in the coastal environment. Erosion can lead to the destabilization and degradation of cultural and recreational sites as well as of wildlife habitats (e.g., for ground-nesting birds). There are well established techniques for restoring rye grasses and other plants on coastal dune systems, including at some sites in Alaska. It is necessary, however, to first identify sites at which damage has occurred and restoration efforts appear to be feasible, and it is also necessary to establish the cost of a full-scale restoration project in the EVOS area.

OBJECTIVES

A. Determine the distribution and areal extent of supratidal sites at which beach wildrye restoration efforts will be needed and feasible.

B. Identify potential sites for pilot projects to re-establish supratidal stands of beach wildrye.

C. Determine the costs of implementing a full-scale project to restore supratidal stands of beach wildrye.

Relationships with Other Studies:

This feasibility study addresses a key component in supratidal beach ecosystems. It relates directly to other feasibility studies and potential restoration projects in the areas of cultural, recreational, and avian resources.

METHODS

Beach segment survey data, aerial photographs, on-site inspections, and other sources of coastline status data will be used for a preliminary identification of sites where stands of beach wildrye have been injured and erosion is occurring or may occur as a result. Based on these preliminary results, individual sites will be visited and evaluated for their potential as sites at which beach wildrye restoration techniques may be developed and tested. The on-ground activities will include documenting the size, type, and extent of damage and the depth of oil, if present, in the substrate. This study will enable development and evaluation of a proposal for a full-scale feasibility study of restoration methods in subsequent years.

BUDGET: DNR

Salaries	$ 14.4
Travel	5.6
Contractual Services	5.0
Supplies	3.1
Equipment	0.0
TOTAL	$ 28.1

RESTORATION FEASIBILITY STUDY NUMBER 4

Study Title: Identification of Upland Habitats Used by Wildlife Affected by the EVOS

Lead Agency: FWS

Cooperating Agency: ADF&G

INTRODUCTION

A variety of marine birds, waterfowl, and other bird and mammalian species were killed by the spill or injured by contamination of their prey and habitats. Many of these wildlife species are dependent on aquatic or intertidal habitats for such activities as feeding and resting, but they use upland habitats in forests, along streams, or above tree line to fulfill other life-history requirements (e.g., nesting, shelter). Through the public scoping process and technical workshop, many people have suggested that protection of upland wildlife habitats from further degradation may be an important way to help wildlife recover from the effects of EVOS. To explore this potential, it is necessary to learn more about the specific upland habitats upon which these species depend and how they use them. While such a feasibility study would be a large and complex undertaking, an initial study that primarily focuses on the marbled murrelet (*Brachyrumphus marmoratus*) and the harlequin duck (*Histrionicus histrionicus*) will be conducted in 1990. The results of this study will provide a basis for developing and evaluating a broader feasibility study proposal that will more fully explore the ecological relationship between marine-dependent wildlife and upland habitats.

OBJECTIVES

Objectives A-C specifically apply to both harlequin ducks and to marbled murrelets, the primary subjects of the 1990 study:

A. Develop and test methods for establishing the presence of breeding birds.

B. Develop and test methods for locating nest sites.

C. Identify and characterize nest habitats and sites.

D. Define the parameters of and develop a proposal for a full-scale upland habitat feasibility study for marine birds, waterfowl, and other species.

E. Determine the costs of implementing a full-scale restoration project concerning upland habitats used by marine-dependent wildlife.

Relationships with Other Studies:

This study relates directly to the results and field work of Bird Studies 2 and 11 and RF 5.

METHODS

Marbled murrelet: Naked Island in PWS will be the primary study site. The presence of breeding murrelets will be recorded by a stationary observer at dawn, at which times murrelets fly to inland nest sites. Murrelet altitude, behavioral, and other data will be recorded for each bird observed. Sites with high murrelet activity will be identified and then searched for nests. The efficacy of the dawn detection technique will be evaluated.

Harlequin duck: Streams in PWS will be selected for investigation based upon reported concentrations of ducks, survey data from NRDA projects, and interviews with knowledgeable field personnel. Once streams are identified as having a high potential for harlequin nests, there will be intensive ground searches for nests. As nests are located, the nest sites and habitats will be characterized by such parameters as distance from the stream and coast, topography, and vegetative cover.

BUDGET: FWS, ADF&G

Salaries	$13.3
Travel	1.0
Contractual Services	3.0
Supplies	2.5
Equipment	3.5
Total	23.3

RESTORATION FEASIBILITY STUDY NUMBER 5

Study Title: Land Status, Uses, and Management Plans in Relation to Natural Resources and Services

Lead Agency: DNR

Cooperating Agencies: USFS, NPS, ADF&G

INTRODUCTION

Through the restoration scoping process members of the public have suggested a wide variety of projects to acquire equivalent resources. Examples are the acquisition of timber or development rights, conservation easements, recreational and cultural sites, inholdings within state and federal protected areas, and buffer strips along streams and coasts. In addition, scientists participating in the technical workshop found that in some cases habitat protection projects would be the best means of providing for the long-term restoration of injured wildlife resources. In order to begin to identify and evaluate potential restoration projects of this type, it is necessary to summarize existing information about the land status, uses, and management plans for both privately and publicly owned lands. This initial effort will focus on the oil-spill area and adjacent lands and will also serve to identify potential sites for other types of restoration projects.

OBJECTIVES

A. Summarize and map the land status and ownership, land-use designations, and existing and proposed uses of tidelands and related uplands.

B. Summarize and map the extent and degree of oiling and coastal morphology as necessary for restoration planning purposes.

C. Summarize and map natural resources and services, including vegetation, fish and wildlife populations, habitats, and sensitive areas, recreation, and commercial forestry.

Relationships with Other Studies:

These data are fundamental to the entire Restoration Planning Project and especially to those feasibility studies and potential restoration projects that concern the acquisition of equivalent resources.

METHODS

The DNR, through the NRDA Study TS 1, has compiled much of the necessary data on their computerized G.I.S. Additional resource and land use information is available in state and federal management plans and resource inventories and from the Alaska Coastal Management Program. The RPWG and technical advisors will be consulted to define the specific area and information needs, which will then be obtained from the various existing data bases. After determining the most feasible means and best resolution to portray the information, it will be summarized, produced, and distributed, primarily in map form.

BUDGET: DNR

Salaries	$	34.0
Travel		1.0
Contracts		5.0
Supplies		10.0
Equipment		0.0
Total	$	50.0

PART IV

BUDGET

Budget Summary for the Exxon Valdez Oil Spill Damage Assessment - 1990
Budgets are in 1000's of Dollars

Budgets are costs for projects from 3-1-90 through 2-28-91

Study Category	Number	Title	Agency	Budget
Coastal Habitat	CH1	Comprehensive Assessment	ADF&G	$ 156.7
			USFS	9,113.0
Air/Water	A/W2	Injury to Subtidal	ADF&G	333.5
			NOAA	466.8
	A/W3	Hydrocarbons in Water	DEC	47.5
			NOAA	472.5
	A/W6	Oil Fate and Toxicity	NOAA	870.0
Fisheries	F/S1	Salmon Spawning Area Injury	ADF&G	391.5
	F/S2	Egg and Preemergent Fry Sampling	ADF&G	302.8
	F/S3	Coded-Wire Tagging	ADF&G	1,990.0
	F/S4	Early Marine Salmon Injury	ADF&G	150.0
			NOAA	400.0
	F/S5	Dolly Varden Injury	ADF&G	290.0
	F/S7a	Salmon Spawning Area Injury, LCI	ADF&G	117.6
	F/S7b	Salmon Spawning Area Injury, Kodiak & Chignik	ADF&G	460.3

Budget Summary for the Exxon Valdez Oil Spill Damage Assessment Program
Budgets are in 1000's of Dollars

Budgets are costs for projects from 3-1-90 through 2-28-91

Study Category	Number	Title	Agency	Budget
Fisheries	F/S8a	Egg & Preemergent Fry Sampling, LCI	ADF&G	71.0
	F/S8b	Egg & Preemergent Fry Sampling, Kodiak & Chignik	ADF&G	149.3
	F/S11	Herring Injury	ADF&G	558.4
	F/S13	Clam Injury	ADF&G	229.2
	F/S15	Spot Shrimp Injury	ADF&G	65.0
	F/S17	Rockfish Injury	ADF&G	109.4
	F/S18	Trawl Assessment in PWS	NOAA	186.1
	F/S22	Crab Injury, Outside PWS	NOAA	110.0
	F/S24	Trawl Assessment, Outside PWS	NOAA	450.0
	F27	Sockeye Salmon Overescapement	ADF&G	392.0
	F28	Run Reconstruction	ADF&G	175.1

Budget Summary for the Exxon Valdez Oil Spill Damage Assessment Program
Budgets are in 1000's of Dollars

Budgets are costs for projects from 3-1-90 through 2-28-91

Study Category	Number	Title	Agency	Budget
	F30	Data Base Management	ADF&G	120.0
Marine Mammals	MM1	Humpback Whale	NOAA	92.0
	MM2	Killer Whale	NOAA	255.8
	MM4	Sea Lion	NOAA	171.2
	MM5	Harbor Seal	NOAA	159.3
	MM6a	Sea Otter Injury	FWS	1,060.5
	MM6b	Sea Otter Mortality Comparisons	FWS	11.0
	MM6c	Sea Otter Drift Study	FWS	33.5
	MM7	Sea Otter Rehabilitation	FWS	147.0
Terrestrial Mammals	TM1	Injury to Sitka Black-Tail Dear	ADF&G	124.6
	TM2	Injury to Black Bear	ADF&G	10.0
	TM3	Injury to River Otter	ADF&G	347.6

Budget Summary for the Exxon Valdez Oil Spill Damage Assessment Program
Budgets are in 1000's of Dollars

Budgets are costs for projects from 3-1-90 through 2-28-91

Study Category	Number	Title	Agency	Budget
	TM4	Injury to Brown Bear	ADF&G	125.7
	TM6	Reproduction of Mink	ADF&G	134.0
Birds	B1	Beach Bird Survey	FWS	598.0
	B2	Censuses & Seasonal Distribution	FWS	471.0
	B3	Seabird Colony Surveys	FWS	251.1
	B4	Bald Eagles	FWS	675.0
	B5	Peale's Peregrine Falcons	FWS	107.7
	B11	Sea Ducks	FWS	150.0
	B13	Passerines	FWS	10.0
Technical Services	TS1	Hydrocarbon Analysis	NOAA FWS	914.2 1,089.2
	TS2	Histopathology	ADF&G	100.0

Budget Summary for the <u>Exxon Valdez</u> Oil Spill Damage Assessment Program
Budgets are in 1000's of Dollars

Budgets are costs for projects from 3-31-90 through 2-28-91

Study Category	Number	Title	Agency	Budget
	TS3	GIS	DNR	592.2
			FWS	200.0
	ARCH1	Archeology	USFS	932.0
			DNR	300.0
Restoration Planning	RP1	Restoration Planning	ALL	1,762.9
Overhead		State of Alaska	ADF&G	1,745.0
		Dept. of Agriculture	USFS	1,245.0
		Dept. of Interior	FWS	500.0
		Dept. of Commerce	NOAA	953.8
		Environmental Protection Agency	EPA	44.1
Discontinued Studies Completion		All Agencies		140.0

Budget Summary for the Exxon Valdez Oil Spill Damage Assessment Program
Budgets are in 1000's of Dollars

Budgets are costs for projects from 3-1-90 through 2-28-91

Study Category		Management Entity	Agency	Budget
Economics	ECON1	Commercial Fisheries Losses	ALL FED	229.0
	ECON4	Public Land Value Effects	ALL FED	180.0
	ECON5	Recreational Uses Damage	ALL FED	294.0
	ECON6	Subsistence Losses	ALL FED	885.0
	ECON7	Intrinsic Value Loss	ALL FED	2,010.0
	ECON8	Research Program Damage	ALL FED	51.0
	ECON9	Archeological Resource Damage	ALL FED	50.0
TOTALS				$37,330.2

Trustee Budget Summary for the Exxon Valdez Oil Spill Damage Assessment Program
Budgets are in 1000's of Dollars

Budgets are costs for projects from 3-1-90 through 2-28-91

Trustee		Budget
State of Alaska	$	10,504.9
Department of Agriculture		11,545.4
Department of the Interior		5,559.4
Department of Commerce		5,757.0
Environmental Protection Agency		264.5
All Federal		3,699.0
TOTALS	$	37,330.2

APPENDICES

APPENDIX A

STATE/FEDERAL DAMAGE ASSESSMENT PLAN

ANALYTICAL CHEMISTRY

QUALITY ASSURANCE (QA)/QUALITY CONTROL (QC)

TABLE OF CONTENTS

Appendix A (continued)

This document describes the Quality Assurance for the analytical chemistry portions of the Exxon Valdez Damage Assessment Process. It is to be used in conjunction with the Analytical Chemistry Quality Assurance Programs of the Trustee Agencies. It describes only those minimum requirements necessary to validate the data generated by analytical chemistry laboratories. Quality assurance requirements for other types of measurements are not addressed.

For instructions in meeting the requirements described in this document, please consult "Collection and Handling of Samples," which was prepared by the Analytical Chemistry Group for use in training field personnel or the following Agency representatives:

Carol-Ann Manen, National Oceanic and Atmospheric Administration, (907) 789-6014.

Everett Robinson-Wilson, U.S. Fish and Wildlife Service, (907) 786-3493.

Rolly Grabbe, Alaska Department of Environmental Conservation, (907) 364-2155.

John Moore, U.S. Fish and Wildlife Service, (301) 497-0524.

Appendix A (continued)

1. Quality Assurance for Analytical Chemistry

Each Trustee agency through their individual standard documented QA programs and guidances shall ensure that all data generated by or for that agency and their contractors, in support of the Exxon Valdez Damage Assessment, are of known, defensible, and verifiable quality.

These documented QA programs and guidances include but are not limited to:

- NOAA National Status and Trends Program, Mussel Watch Phase 4 Work/QA Project Plan
- Quality Assurance of Chemical Analyses Performed Under Contract With the USFWS
- EPA SW-846, Chpt. 1, QA/QC Requirements
- EPA Guidelines and Specification for Preparing Quality Assurance Project Plans, QAMS-005
- EPA Handbook for Sampling and Sample Preservation of Water and Wastewater

In addition, an interagency team of leading scientists from the Trustee agencies and the Environmental Protection Agency, hereafter referred to as the Analytical Chemistry Group (ACG), shall develop and oversee a centralized program which will demonstrate the quality and comparability of the chemical data obtained by the Trustee agencies.

The major components of this centralized QA program will be:

1. Development of study-specific analytical chemistry QA plans.

2. Technical on-site system audits of field and laboratory data collection activities.

3. Development and provision of appropriate instrument calibration standards and control materials.

4. Laboratory performance evaluations by means of intercomparison exercises.

5. Review of data deliverables and all supportive documentation to evaluate data quality.

1.1 Study-Specific Quality Assurance Plans

Prior to the initiation of each study, the study manager must prepare and submit a study-specific analytical chemistry QAP to the ACG for review and concurrence. This plan shall specify each study's goals, sampling procedures, analytical procedures, and all quality control measures and acceptance criteria associated with those procedures.

The QAP must be study-specific, however any documented QA guidance and/or appropriate Standard Operating Procedures (SOP's) used by the Trustee agencies may form the basis of individual study QA plans.

A Quality Assurance Plan must address the following:

* Title Page - Includes the signatures of the individuals responsible for the project and ACG concurrence.

* Project Description and Sampling Objectives - Briefly describes the what, where, and why of the project.

* Data Needs - Describes what elements, compounds, classes of compounds, and/or physical data are required. Must describe the desired detection limits, precision and accuracy of the data for the study.

* Sampling and Labelling Procedures - Describes sample collection, including field QC and preservation. Estimates the number and kind of samples to be collected. Minimum requirements for sample collection are described in Section 2.

* Chain of Custody - Describes Chain-of-Custody and documentation procedures. Minimum requirements are described in Section 2.

* Analytical Procedures - References or describes in detail proposed method(s).

* Internal Quality Control - Describes type and frequency of internal quality control. Minimum requirements are described in Section 3.

* Calibration Procedures and Frequency - Describes the methods and frequency for calibrating field and laboratory instruments. These must be specified in SOP's.

* Data Verification - Describes the data verification in SOP form and includes; (1) the methods used to identify and treat outliers, and (2) the data flow from generation of raw data through storage of verified results.

* Data Deliverables - Specifies reporting needs additional to the minimum requirements described in Section 4.

* Technical System and Performance Audits - Specifies field or intra-laboratory audits planned by the responsible Agency.

1.2 Technical System Audits

On-site system audits may be performed without prior notification by the ACG after consultation with the responsible agency.

1.3 Standards and Quality Control Materials

The National Institute of Standards and Technology (NIST) will develop and provide appropriate standards and quality control materials.

1.4 Analytical Performance Evaluations

Prior to the initiation of work, each analytical laboratory will be required to demonstrate its capability. This will be accomplished by providing laboratory documentation on the performance of the proposed methods and through the analysis of an accuracy based material. The results of this analysis must be within +/- 15% of the value of each analyte or measurement parameter.

Any changes in analytical methodology from that proposed in the original QA plan shall be validated under agency procedures and documented to the ACG.

A series of three intercomparison exercises, utilizing the blind analysis of gravimetrically prepared materials, extracts of environmental matrices (tissue, sediment and water) or the matrices themselves, will be conducted annually. Participation in these exercised is mandatory. Materials will be prepared by, and data returned to the NIST for statistical analysis. The NIST will report to the chairperson of the ACG. Unacceptable performance will result in the discarding of the associated data.

The ACG will review and provide written reports on the results of intercomparison studies to the Management Team.

1.5 Data Reporting and Deliverables

Data deliverables will be reviewed by the generating Agency to verify the quality and useability of the data. A QC report on each data set will be provided to the ACG for review.

All data and associated documentation will be held in a secure place under chain-of-custody procedures until the Trustees indicate otherwise.

2. Minimum Requirements: Sampling and Sampling Equipment

Sample collection activities must be described in SOP's. References to existing documents are acceptable.

The method of collection should not alter the samples.

Sample collection and storage devices shall not alter the sample.

Samples shall be held in a secure place under appropriate conditions and under chain-of-custody until the Trustees indicate otherwise.

2.1 Sampling Identification and Labelling

An SOP will be in place for each study which describes procedures for the unique identification of each sample. A sample tag or label will be attached to the sample container. A waterproof (indelible) marker must be used on the tag or label. Included on the tag are the sample identification number, the location of the collection site, the date of collection and signature of the collector.

The information above will also be recorded in a field notebook along with other pertinent information about the collection and signed by the collecting scientist.

2.2 Field Chain-of-Custody

The field sampler will be personally responsible for the care and custody of the samples collected until they are transferred to another responsible party.

Samples will be accompanied by a chain-of-custody record or field sample data record. When samples are transferred from one individual's custody to another's, the individuals relinquishing and receiving will sign, date and note the time on the record.

Shipping containers will be custody-sealed for shipment. Whenever samples are split, a separate chain-of-custody record will be prepared for those samples and marked to indicate with whom the samples are being split.

Samples shall be maintained in a manner that preserves their chemical integrity from collection through final analysis.

Sample shipper will arrange for sample receipt.

After analysis, any remaining sample and all sample tags, labels and containers shall be held under chain-of-custody procedure until the Trustees indicate otherwise.

3. Minimum Requirements: Analysis

The applicable methodology must be referenced or described in detail in the SOP's for each measurement parameter.

Method limits of detection must be calculated by matrix and analyte.

Control of the analytical method in terms of accuracy and precision must be demonstrated.

Calibration must be verified at the end of each analysis sequence.

Samples must be quantified within the demonstrated linear working range for each analyte.

Standard curves must be established with at least 3 points besides 0.

Field blanks, procedural blanks, reference materials, replicates and analyte recovery samples must be run at a minimum frequency of 5 percent each per sample matrix batch.

A minimum list of the petroleum hydrocarbon compounds which are to be considered for identification and quantification in water, tissue and sediment include the volatiles, i.e., benzene, toluene, xylene and the polynuclear aromatic and aliphatic hydrocarbons listed below:

Naphthalene	n-dodecane
2-Methylnaphthalene	n-tridecane
1-Methylnaphthalene	n-tetradecane
Biphenyl	n-pentadecane
2,6-Dimethylnaphthalene	n-hexadecane
Acenaphthylene	n-heptadecane
Acenaphthene	pristane
2,3,5-Trimethylnaphthalene	n-octadecane
Fluorene	phytane
Phenanthrene	n-nonadecane
Anthracene	n-eicosane
1-Methylphenanthrene	
Fluoranthene	
Pyrene	
Benz(a)anthracene	
Chrysene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Benzo(a)pyrene	Benzo(e)pyrene
Indeno(1,2,3-c,d)pyrene	Perylene
Dibenz(a,h)anthracene	
Benzo(g,h,i)perylene	

4. <u>Minimum Requirements: Reporting and Data Deliverables</u>

Measurement results, including negative results, as if three figures were significant must be reported.

Results of quality control samples analyzed in conjunction with the study samples must be reported.

Documentation demonstrating analytical control of precision and accuracy on an analyte and matrix specific basis must be reported.

APPENDIX B

EXXON VALDEZ OIL SPILL DAMAGE ASSESSMENT PLAN
HISTOPATHOLOGY GUIDELINES

Histopathology is an important tool used in determining mechanisms of death and sublethal effects caused by infectious agents and toxic substances. A definitive diagnosis often does not result from histological examination, but can give strong support to other positive measurements. Tissues deteriorate (autolyze) rapidly after an animal dies; therefore, to be of value, any samples taken for histological evaluation as part of the damage assessment of the Exxon Valdez oil spill must be collected, preserved, and processed under strict guidelines.

Sample Collection and Preservation Protocols

Standard protocols for necropsy and preservation of tissue samples for histopathology shall be used throughout the oil spill assessment studies. Different protocols have been designed to accommodate the different groups of animals to be encountered in the assessment studies. Necropsy procedures have been established and provided to study managers under separate cover for a variety of different animal groups including finfish, bivalve mollusks, brachyuran and crab-like anomurans (i.e., king crabs), shrimp, marine and terrestrial mammals, and migratory and nonmigratory waterfowl.

Paired sampling of animals from oiled versus non-oiled sites will be done for comparative purposes. Histopathological sampling should be done during any observed acute episodes of mortality or morbidity to determine the cause of death or abnormality. These types of samples are the most valuable in assessing acute toxicity affects and will be the most likely samples collected for birds and mammals due to their high visibility in the impacted areas. Because of the low visibility of fish and shellfish, many histology samples will consist of random collections in impacted and control areas with little prior obvious indication of morbidity or mortality.

Any histological processing of samples collected from apparently normal shellfish will be performed after results of parallel hydrocarbon sampling are known; i.e., positive hydrocarbon results may merit further histopathology studies. This would not be advisable for fish and other higher animals that possess an active mixed function oxidase (MFO) liver enzyme system which could metabolize hydrocarbons to other compounds providing negative hydrocarbon results, while potentially still exhibiting toxicological lesions. Analyses of enzyme function may show an activated MFO system in exposed fish and higher animals. Consequently, histology and hydrocarbon samples, as well as other appropriate samples, such as liver and bile, will be taken from the same animal when possible for analyses of metabolites and enzyme function. If certain fish and shellfish are too few or small, subsampling other animals from the same site at the same time will be necessary.

Processing and Interpretation Protocols

Histopathology assessment of birds and mammals will be done primarily on tissues from clinically affected animals using established criteria of cellular degenerative and necrotic changes recognized by a board certified veterinary pathologist.

Histopathological analysis of finfish and shellfish tissues will include the criteria above as well as indices established in the *Amoco Cadiz* oil spill studies (Haensly, et al., 1982; Berthou, et al., 1987) to allow some quantification of potentially subtle degenerative changes in tissue histology of otherwise clinically normal animals. Briefly, these indices include mean concentration of mucus cells per mm^2 of gill lamellae (fish); mean concentration of mucus cells per mm of epidermis in 10 fields (fish); mean concentration of macrophage centers per mm of liver; mean concentration of hepatocellular vacuolation due to fatty degeneration (fish); a mean and total tissue necrosis index (invertebrates); histological gonadal index (invertebrates); and differences in prevalences and intensities of incidental lesions caused by infectious agents (fish and invertebrates).

Quality Assurance in Field Collection of Samples and in Interpretation of Results

Field Collection:

Veterinary personnel trained in sample taking will be utilized for onsite necropsies of birds and mammals in order to ensure adequate quality control and standardized sample collection. The same high standards will be attainable in fish and invertebrates in that sample collection will be done by trained finfish and shellfish biologists. A fish pathologist and technician are available to train field personnel and assist in necropsy and preservation of finfish and shellfish samples at collection sites.

Finfish and shellfish samples can be coordinated through an ADF&G fish pathologist, Fisheries Rehabilitation, Enhancement and Development Division.

Interpretation of Results:

Quality control of all processed work will require independent blind reading of subsampled histology slides by two different laboratories. Tissues with known lesions will be included periodically in groups of tissue samples for blind reading and determination of competency in interpretation.

Chain of Custody Guidelines

Due to the evidentiary nature of sample collecting investigations, the possession of samples will be traceable from the time the samples are collected until they are introduced as evidence in legal proceedings. To maintain and document sample possession, chain of custody procedures will be followed.

The field sampler will be personally responsible for the care and custody of the samples collected until they are transferred. All samples will be accompanied by a chain of custody record and will be custody-sealed. This procedure includes use of a custody seal such that the only access to the package is breaking the seal. When samples are transferred from one individual's custody to another's, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents the transfer of custody of samples from the sampler to another person and, ultimately, to a specified analytical laboratory.

Shipping containers will also be custody-sealed for shipment. The seal shall be signed before the sample is shipped. The chain of custody record will be dated and signed to indicate transfer. The original record will accompany the shipment and a copy will be retained by the sample collector. Whenever samples are split, a separate chain of custody record will be prepared for those samples and marked to indicate with whom the samples are being split. If samples are being sent by common carrier, copies of all bills of lading or air bills must be retained as part of the permanent documentation.

Subcontracting for Histological Work

Subcontracting work for histopathology processing and interpretation will be under the control of an interagency team referred to as the Histology Technical Group which will determine if potential contractors are qualified to do the work. Qualifications for mammal and avian samples will require a board certified veterinary pathologist. Finfish and shellfish work will require individuals with a demonstrated publication record in the field of histopathology.

References

Bell, T.A., and V.V. Lightner. 1988. A Handbook of Normal/Penaeid Shrimp Histology. The World Aquaculture Society, Baton Rouge, LA.

Berthou, F., G. Balouet, G. Bodennec, and M. Marchand. 1987. The occurrence of hydrocarbons and histophatological abnormalities in oysters for seven years following the wreck of the Amoco Cadiz in Brittany (France). Mar. Environ. Res. 23:103-133.

CERCLA. 1988. Natural Resource Damage Assessments. 53 Federal Regulation 5166 and 9769.

Haensly, W.E., J.M. Neff, J.R. Sharp, A.C. Morris, M.F. Bedgood, and P.D. Boem. 1982. Histopathology of Pleuronectes platessa L. from Aber Wrac'h and Aber Benoit, Brittany, France: long-term effects of the Amoco Cadiz crude oil spill. J. Fish Dis. 5:365-391.

Sparks, A.K. 1985. Synopsis of Invertebrate Pathology Excluding Insects. Elsevier Publ., New York.

APPENDIX C

GLOSSARY OF TERMS, ACRONYMS

ADF&G	Alaska Department of Fish and Game
AFK	Armin F. Koernig Fish Hatchery
AHs	Aromatic Hydrocarbons
AHH	Aryl Hydrocarbon Hydroxylase
ANOVA	Analysis of variance
A/W	Air/Water
AWL	Age, Weight, Length
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
C/H	Coastal Habitat
CI	Cook Inlet
CIK	Cook Inlet/Kenai
CTD	Conductivity/temperature/depth
CWA	Clean Water Act
CWT	Coded wire tag
DEC	Alaska Department of Environmental Conservation
DNR	Alaska Department of Natural Resources
DOA	Department of Agriculture
DOC	Department of Commerce
DOI	Department of the Interior
DOJ	Department of Justice
DBMS	Database Management System
EPA	Environmental Protection Agency
E/S	Economic Study
EVOS	Exxon Valdez Oil Spill
FRED	Fisheries Rehabilitation, Enhancement and Development Division, ADF&G
F/S	Fish/Shellfish
FWS	U.S. Fish and Wildlife Service
GC-MS	Gas chromatography-mass spectrometry
GOA	Gulf of Alaska
KAP	Kodiak Archipelago/Alaska Peninsula
KP	Kenai Peninsula
LCI	Lower Cook Inlet
MFO	Mixed function oxidase
MLLW	Mean lower low water
M/M	Marine Mammal
NIOSH	National Institute of Occupational Safety and Health
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPH	Naphthalene
NPS	National Park Service

APPENDIX C

GLOSSARY OF TERMS, ACRONYMS

NRDA	Natural Resource Damage Assessment
NSO	Nitrogen-sulphur-oxygen
PED	Potential egg deposition
PHN	Phenanthrene
PI	Principal Investigator(s)
PWS	Prince William Sound
PWSAC	Prince William Sound Aquaculture
QA/QC	Quality Assurance/Quality Control
RPWG	Restoration Planning Work Group
SCAT	Shoreline Cleanup Advisory Team
SSAT	Spring Shoreline Assessment Team
T/M	Terrestrial Mammals
T/S	Technical Services
USFS	United States Forest Service
VFDA	Valdez Fisheries Development Association

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The 1990 State/Federal Natural Resource Damage Assessment and Restoration Plan for the Exxon Valdez Oil Spill

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GENERAL

COMMENTS AND RESPONSES CONCERING THE DRAFT "STATE/FEDERAL NATURAL RESOURCE DAMAGE ASSESSMENT PLAN FOR THE EVOS"

The 1989 Draft Damage Assessment Plan was made available to the public for review and comment. Approximately 75 reviewers representing industry, environmental groups, public agencies and individuals commented on the plan during the written comment period and the follow-up oral sessions held in Anchorage, Alaska and Washington, D.C. Reviewers commented on the overall nature and content of the plan and provided technical remarks concerning many of the individual studies. All comments were considered by the Trustees during evaluation of the 1989 effort and formulation of the current plan.

This section provides a synthesis of the comments and responses thereto. Comments were not individually identified since many comments were either similar or duplicative. The comments and responses are organized into two basic categories -- those dealing with the general nature of the plan and those concerning a specific category of studies or individual studies.

Comments concerning individual studies that have been completed or discontinued in 1990 have not been addressed in this plan.

GENERAL COMMENTS

Comment: Reviewer had been wrongly identified as a "potentially responsible party" (PRP) as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 USC. Sec. 601(14) expressly exempts "petroleum, including crude oil" as a substance to be considered under the provisions of that law, and liability extends only to the owner of the vessel from which the oil was spilled under the Clean Water Act (CWA), 33 USC. Sec. 1321.

Response: The natural resource damage assessment studies are not designed to determine the liability of a particular party, hence the term "potentially responsible party" is used. The focus of the process is to identify, quantify, and value injury to natural resources due to the EVOS, and to identify appropriate restoration measures. The Trustees are confident that the applicable laws have been interpreted correctly, including those relating to identification of PRPs.

Comment: The plan lacked sufficient detail to evaluate the adequacy of individual studies in assessing injury to natural resources.

Response: The objective of the 1989 plan was to provide summary information on individual studies, adequate for reviewers to understand the scope of the study and the interrelationships between studies, as well as the scope of the overall damage assessment program. Greater detail is included in the current plan.

Comment: The plan lacked sufficient detail for reviewers to determine whether the statistical designs were adequate to produce valid results. The overall design of some studies would not produce valid results.

Response: All studies were fully reviewed in terms of statistical design and other factors. As a result of this review, some studies were discontinued and others were modified to ensure a statistically valid design. More detail on statistical methods is included in the current plan.

Comment: There was insufficient detail to determine whether the methods for collection, cataloging, storage, preservation and analysis of field samples and other data are adequate. There was also insufficient detail on the costs of the studies.

Response: A detailed protocol has been developed for the collection, cataloging, and storage of field samples and related data to ensure that a proper chain of evidence is maintained and that information is preserved. (All individuals collecting samples have been trained in these methods.) This protocol is described in the Quality Assurance/Quality Control Procedures for the damage assessment plan. (See Appendix A.) These procedures also describe the quality assurance methods for laboratory analysis. Costs of studies are detailed in the current plan.

Comment: There was insufficient consideration of the natural recovery of resources in the discussion of restoration. The goal of this process should be to restore the spill-affected area to a pristine condition rather than to restore necessary services.

Response: Natural recovery of resources will be considered in restoration planning. A review of literature will be completed to provide information about natural recovery from other oil spills, as well as other methods of restoration. The goal of restoration is to restore the affected area to a pre-spill condition where possible. More detail is provided in the restoration section of the plan.

Comment: There is no Restoration Methodology Plan or resource recoverability analysis in the plan.

Response: The primary objective of the 1989 effort was to examine the injury to natural resources as a first step in determining damages and appropriate restoration. Restoration planning was initiated in November 1989, and will include methodology planning. Details of restoration planning are provided in this plan.

Comment: There was insufficient information regarding design and costs of the studies to determine whether the costs were reasonable, as defined in the NRDA regulations.

Response: Because of the need to gather information in a timely manner, studies were implemented in 1989 consistent with 43 C.F.R. Section 11.22 of the NRDA regulations. During the winter, all studies were reviewed in detail to ensure that study designs and costs were consistent with the regulatory provisions for reasonable costs. As a result, some studies were discontinued and others were modified. Greater detail is provided in the current plan.

Comment: There were errors in the chronology of oil spill events.

Response: The chronology has been reviewed where it has a bearing on the damage assessment process. The 1990 plan has eliminated the chronology.

Comment: The plan did not include sufficient study of animals that use beach habitat on Kodiak Island.

Response: See current plan for studies concerning Kodiak Island. In addition, beach animals are being studied in other locations. Findings from these studies will be extrapolated to other affected areas where appropriate.

Comment: The studies focus on the effects of oil on individual species and do not consider the interrelationships between species as well as interactions within the ecosystem as a whole. In addition, the damage assessment process is limited to an assessment of loss for human use and should include a consideration of use, non-use and loss of service to the ecosystem as whole.

Response: The studies are intended to provide a comprehensive assessment of injury to the ecosystems affected by the oil spill. For example, one objective of the coastal habitat study is to link effects identified in individual studies to the ecosystem as a whole. During the winter review of studies, several studies were modified and additional studies were included in the plan to further enhance analysis of the interrelationships among species. The Damage Assessment will evaluate the intrinsic value of resources as well as their use values, and will consider both services to humans and to other parts of the ecosystem.

Comment: The effects of natural variation cannot be considered adequately without long-term studies.

Response: As a result of the winter review, it is anticipated many studies will be continued.

Comment: The effects of cleanup need to be evaluated.

Response: Where appropriate, the 1990 studies including the coastal habitat study, have been modified to evaluate the effects of cleanup.

Comment: The damage assessment studies did not include the potential effect of the spill on the tourist industry.

Response: The economic studies will consider effects on the tourist industry.

Comment: The plan lacks objectivity and focuses on the liability of Exxon.

Response: The intent of the plan is to determine injury to natural resources and assess appropriate damages as compensation. The plan has been reviewed by scientists outside the government to ensure objectivity. The plan is not intended to establish the liability of any potentially responsible party.

Comment: The plan does not adequately assess damage to natural resources in the GOA and CI.

Response: As a result of the winter review, some studies have been modified to better determine injury to resources in the GOA and CI.

Comment: All studies should be given adequate review to ensure that progress is satisfactory.

Response: The damage assessment process requires program managers to ensure the satisfactory progress of studies. Also, studies will be reviewed periodically by scientists from outside the government.

Comment: There is no study of toxicology in the A/W studies.

Response: A study of toxicology has been done as a part of response activities, and an additional study of toxicology in Air/Water #6 has been added to the damage assessment as a result of the winter reviews. See the 1990 study plans.

Comment: The damage assessment plan is a macro-evaluation of loss and should consider specific sites and industries.

Response: The studies provide an assessment of some specific sites and industries as well as a more comprehensive assessment of overall injuries.

Comment: There is no provision in the plan for long term studies to address chronic injuries.

Response: As a result of winter reviews, several studies will be continued in 1990. It is contemplated that after further review, some studies may be continued in future years which will assist in identifying chronic injuries.

Comment: Information on ocean circulation was not used in determining areas to be studied. Specifically, how far will studies extend along the Alaska Peninsula, and why were regions east of the peninsula eliminated from study?

Response: The spread of oil has been tracked by ADEC and NOAA and studies have been expanded to include the affected area. The assessment is intended to address representative areas that have been significantly contaminated by oil, although not every contaminated area is being studied.

Comment: Who in NOAA identified sensitive areas needing protection referred to on page 8, line 22 and when?

Response: In 1988, NOAA's Ocean Assessment Division published a set of maps for Prince William Sound that identified environmentally sensitive areas for biological resources by season and location. These maps were referred to extensively during early spill response activities.

Comment: There is a lack of modeling to tie measurement studies into a unified framework.

Response: Modeling has been incorporated, where appropriate, into particular studies.

Comment: The plan does not fully explain the sources of funding for the damage assessment studies.

Response: Exxon Shipping Company provided $15 million for the studies and the remainder of the cost has been provided by the trustee agencies. The Trustees have requested additional funds from Exxon. As of the date of this writing, no response to this request has been received.

Comment: Baseline data does not exist and this may affect the results of the studies.

Response: Where there is a lack of baseline data, non-oiled sites are being used as a control to compare with oiled sites. Greater detail regarding these methods is provided in the current plan.

Comment: How will the public be informed of opportunities to comment on the plan, study revisions, and changes in PRPs?

Response: A response to public comments on the 1989 plan has been included in the 1990 plan. The public may also comment on the current plan.

Comment: There is no summary addressing "the big picture."

Response: The objectives of the plan were presented in the introduction to the document as well as in the introduction to major groups of studies.

Comment: Copies should be made available to Alaska libraries.

Response: Copies of the plan were sent to libraries in the vicinity of the spill. Also, the plan provided an address for individuals to request copies.

Comment: Participation by interested parties during the development of the plan would have produced a more accurate plan.

Response: The urgent need to begin an assessment of potential damages required the planning and implementation of studies in a short time frame. Nevertheless, participation has been provided through the comment and response process.

Comment: "Worst case analysis" methods should be used in determining injury.

Response: A worst case approach is not required or appropriate for damage assessment. An actual case approach is more appropriate.

Comment: The lack of coordination in collection of chemical and biological samples may cause problems in linking injury to Exxon Valdez oil.

Response: The Quality Assurance/Quality Control plan establishes the protocol for collection and analysis of samples. A chemical analysis group was established to direct and monitor sample collection, coordination, and priorities. Sampling sites for all studies have been mapped for reference and coordination by field investigators.

Comment: Damage assessment under the CERCLA guidelines will undervalue the losses to wilderness ecosystems.

Response: The economic studies collectively should address this concern.

Comment: The proposals are poorly designed, are scientifically and legally inadequate, and will produce flawed results. The studies should be reviewed by scientific experts and modified as necessary. There should be provisions for continuous review.

Response: The studies have been reviewed by scientists and others to ensure they meet both scientific and legal requirements.

Comment: A reviewer is not listed as a cooperator in the coastal habitat study.

Response: The reviewer is a contractor on the study. Most contractors are not listed as cooperators.

Comment: Certain studies proposed by reviewers have been omitted from the plan.

Response: All studies have been reviewed and adjustments made in the current plan to ensure an adequate determination of injury to resources. Not all studies considered in the assessment process were conducted.

Comment: There is a need to qualify the use of models to extrapolate long term injuries from data collected over a short time period.

Response: The data base for modeling was evaluated in the review as reflected in the current plan.

Comment: Sample size and replication were not given adequate consideration in the statistical design of studies.

Response: Statisticians were consulted in the original design of studies and were involved in the review to ensure an adequate statistical design. More information on statistical design is included in the 1990 plan.

Comment: Investigators were limited to the analysis of 10 samples in evaluating the first year's results and decisions regarding the continuation of studies were based on these limited samples.

Response: The combination of time constraints and limited laboratory capacity required the setting of priorities and limiting the number of samples analyzed for each study in preparation for the preliminary first year review. These limits on data analysis were considered in the review. The initial submission of 10 samples per study has been supplemented by analysis of hundreds of other samples.

Comment: The plan did not address physical, social and psychological effects on humans, especially native Alaskans.

Response: As provided in CERCLA and the Clean Water Act, the plan addresses injury to natural resources. It indirectly addresses effects on humans by evaluating damages in terms of loss of use or intrinsic values as well as of services to humans.

Comment: Various reviewers expressed either support for or opposition to the Natural Resource Damage Assessment Regulations in 43 C.F.R. Part 11.

Response: The use of Natural Resource Damage Assessment Regulations in 43 C.F.R. Part 11 to assess damages for injury to natural resources as a result of a release of hazardous substances or a discharge of oil is optional. See 43 C.F.R. Section 11.10 (1989). At the time of the spill and the formulation of the Draft Plan, certain portions of the regulations were challenged in litigation before the U.S. Court of Appeals for the District of Columbia. The Trustees decided to leave open the option of whether to follow strictly the regulations. The Draft Plan is consistent with the overall assessment procedure and guidance outlined in 43 C.F.R. Part 11. While the appropriate work identified in the Draft Plan was underway, the Court issued its decision in Ohio v. U.S. Department of the Interior and Colorado v. U.S. Department of the Interior and directed the Department of Interior to repromulgate certain parts of the regulations. The 1990 plan was developed in accordance with the Court's opinion.

Comment: There is not enough work being done on Kodiak Island; many of the effects there will be secondary and will be felt most acutely during the winter months.

Response: The Trustees believe that sufficient effort has been directed towards assessing injury to the natural resources on Kodiak Island.

Comment: The Plan does not provide adequately for documentation and preservation of field samples and other data to be collected. This will preclude meaningful review by other scientists to determine the validity of the study results.

Response: See QA/QC attachment in Appendix A.

Comment: The Plan should not take into account losses of natural resources uses to private parties, including research projects that were affected by the spill. Compensable damages are limited to those for "committed public uses" of natural resources. Notable exceptions are Economic Uses Studies Nos. 1, 2, 3, 4, 6, 7, 8, and 9; Fish/Shellfish Studies Nos. 1, 7, 11, 12, 15, 116, 22, 24, and 25.

Response: "Committed use," as defined by 43 C.F.R. Section 11.14(h), includes a current public use or planned public use. All comments concerning individual studies were considered during the review process.

Comment: Citations to scientific literature are virtually absent.

Response: The 1990 study plans include bibliographies of selected scientific literature.

Comment: The names and credentials of the scientists conducting the studies are missing. Accepted authorities in each field should be consulted in the design and implementation of the proposed studies.

Response: It is unnecessary to list the names of personnel conducting the studies for the purpose of reviewing the studies. Greater detail in the 1990 plans should assist reviewers in evaluating the quality of the studies.

Comment: The Trustees may be studying effects of injury that do not exist on an interim basis or that will be insignificant or speculative in the long run and, therefore, add unnecessarily to the cost of the Plan.

Response: The studies were designed to identify and quantify measurable adverse changes, either long-or short-term, to natural resources caused by the spill. Data collected from the first year's studies were reviewed and the studies were continued, discontinued, or modified, as appropriate.

Comment: Simply measuring injuries without having a unifying modelling framework will not produce any demonstrable losses within an acceptable statistical confidence due to natural variability spatially and temporally. Given this fact, most of the studies could be considered an unreasonable cost. Models should be employed to predict possible levels of effects over at least two to three generations of the longest-lived members of the ecosystem.

Response: Where appropriate, a modelling framework is being considered.

Comment: The Plan fails to study the presence of oil-degrading microbes or the possibility of oil trapped in sediments being reinfused into the system during winter storms.

Response: These elements are part of A/W #2.

Comment: Baseline data were not identified for each of the component studies.

Response: Where available, additional baseline data is supplied in the current plan.

Comment: All data should be placed in a central repository accessible by all interested parties.

Response: The Trustees have proposed such a central data repository.

Comment: Analysis of long-term effects should include direct and indirect causes of mortality of individuals as well as decreased fecundity and survivorship of age classes.

Response: Such analysis is being conducted, where appropriate. See the current plan.

Comment: A more comprehensive plan for measuring petroleum hydrocarbons needs to be developed. It should indicate what oil components will be screened and how they will be measured analytically. It is essential to perform a comprehensive analysis of the change in composition of the oil in the sediments in time by monitoring appropriate classes of hydrocarbon components of the oil. Individual components of the oil should be monitored throughout the study at selected sites covering a wide range of molecular weight size classes.

Response: A new study, A/W #6, will be initiated in 1990 and will address toxicological effects over time.

Comment: The Plan needs detailed studies of changes in microbial diversity, including changes in microbial populations at the spill site and examination of the influence of oil on this diversity.

Response: The A/W #2 has been modified to allow for examination of microbial populations at a variety of locations and depths in PWS.

Comment: The Plan should incorporate some short- and long-term toxicological effects studies.

Response: The A/W #6 will address toxicological effects over time.

Comment: A major scoping conference on the restoration planning process should be held in Alaska early in 1990, prior to the time it is finalized and before the next field season begins.

Response: See the Restoration Section of the current plan.

Comment: Impacts of the spill on the human environment (human health in particular) and on the interrelationships of human beings with other components of the biophysical environment are missing from the studies. In addition, impact on humans in the spill zone and who participated in the cleanup operations should be included in the damages assessment.

Response: The applicable legal authorities provide for recovery of damage for injury to natural resources, not human health. To the extent that health effects impair use of natural resources, this may constitute injury to natural resources and is being studied.

Comment: The NRDA strategy should take into account natural fluctuations in the ecosystem.

Response: The strategy is to take into account such natural fluctuations in the damage assessment process.

Comment: The studies should take into account the potential for freshwater stream discharges to influence fisheries and other biota.

Response: The NRDA strategy is to distinguish spill impacts from such environmental influences.

Comment: The studies will unnecessarily stress animals. Samples should be limited to those taken from dead specimens, individuals, or taken by Natives.

Response: Such limited sampling would not produce an accurate account of the effect of the EVOS. Measures will be taken to avoid unnecessary disturbance while conducting these studies.

Comment: Studies should take into account the possibility of re-oiling and additional cleanup operations in assessing impacts on marine mammals as well as other parts of the ecosystem.

Response: Potential effects of re-oiling and cleanup operations are being considered in the current Plan.

Comment: The Plan should be expanded to evaluate steps being taken to assess the spill response measures with an eye toward improving response efforts during future spills.

Response: This is outside the scope of the damage assessment process. However, this evaluation is being undertaken by other agencies.

Comment: The overall budget should be increased tenfold to carry out the NRDA properly.

Response: The overall budget reflects what has been determined by the Trustees to be necessary to assess damages for injuries to affected natural resources at a reasonable cost.

Comment: There should not be a limit put on the number of samples analyzed for each study.

Response: An adequate sample size will be collected and analyzed for each study.

Comment: The Plan should include an assessment of the effectiveness of cleanup operations and additional injury occasioned by these operations, especially to archeological sites. The Plan fails to state which shoreline cleanup techniques should be continued or abandoned.

Response: See the current plan for the determination of damage to archaeological resources. Recommendations regarding the appropriateness of cleanup techniques are outside the scope of the damage assessment process; however, certain studies are designed to take into account cleanup impacts.

Comment: Studies fail to consider the impact that reduced sea otter populations will have on the movement of carbon through the affected ecosystems and the significance of this to wildlife and fisheries.

Response: The Trustees placed a priority in the injury determination process on direct and sublethal effects on sea otters. It is unlikely that studies on the impact on movement of carbon through the affected ecosystem due to a reduced sea otter population would provide meaningful information on injury. The role of otters in moving carbon through the ecosystem relative to the massive movement of carbon generated by all the other organisms in the spill area, would be difficult to measure.

Comment: Omitted from the Plan are the potential chronic teratogenic, mutagenic and carcinogenic impacts of the spill on wildlife.

Response: Greater detail is provided in the current Plan in the determination of sublethal effects upon natural resources.

Comment: The Plan is too heavily oriented, in terms of the number of studies and the budget, toward fish/shellfish studies. Very little emphasis is placed on studying terrestrial habitats.

Response: The Trustees have concentrated studies in those areas and upon those resources considered most likely to have been significantly affected by the EVOS.

Comment: Methodologies chosen for many of the studies will not produce statistically acceptable results.

Response: The studies have been reviewed, and where appropriate, have been revised.

Comment: The Plan does not indicate how cause and effect links will be made.

Response: More detail is provided in the current Plan.

Comment: Laboratory studies should be undertaken where field experiments are limited or non-existent.

Response: Where appropriate laboratory studies have been incorporated in the current plan. However, not all environmental conditions can be duplicated in laboratories.

Comment: It is impossible to review the proposed study objectives without knowing the results of data collected in 1989.

Response: The Trustees believe that sufficient information has been provided to allow adequate public review of study objectives.

Data is not required to conduct this review.

<u>Comment</u>: The Plan improperly assumes that all resources in the Sound were exposed to oil. The Trustees should confirm exposure of each of the resources to oil before undertaking studies of them.

<u>Response</u>: The resources targeted for study in 1989 were these determined by the Trustees to be most susceptible to effects from the EVOS. As indicated earlier, a review of these studies was conducted following the first year, which resulted in modification, completion or discontinuation of several studies.

<u>Comment</u>: The determination of the baseline should take into account the fact that ecosystems are not static and that natural forces, such as rainfall, currents and temperatures, can have an impact on the number of species in a given location, the extent to which a particular resource is used, and the mortality of individuals of different species. Given the lack of historical information that will be useful in developing a baseline, the Trustees should consider selecting "control areas" that will serve as bases for baseline measurements. Overall, the design for developing a baseline does not ensure scientific validity of the results.

<u>Response</u>: Where baseline data is nonexistent or inadequate, control areas were selected.

<u>Comment</u>: The use of predictive approaches, such as extrapolating short-term losses into the future, in determining the long-term impacts of the spill should be limited.

<u>Response</u>: The Trustees recognize the appropriate use of predictive approaches.

<u>Comment</u>: The Draft Plan lacks the appropriate focus on restorative measures and ignores the role natural recovery processes will have, and the cleanup efforts have had, in determining what those measures should be.

<u>Response</u>: Natural recovery processes are being considered in the NRDA.

<u>Comment</u>: The Plan is biased toward the conclusion that the spill resulted in harm to all natural resources because no consideration was given to the hypothesis that no damage occurred anywhere.

<u>Response</u>: The purpose of the NRDA is to assess the injury to natural resources that occurred as a result of the EVOS. The detailed study plans investigate the hypothesis that damage may not have occurred to the resources being studied.

<u>Comment</u>: The cover page distorts containment and area of the

spill.

Response: The cover page of the 1989 plan was an artist's rendition of the subject matter of the NRDA and was not intended to be a scientifically defensible depiction of the area affected by the EVOS or of the containment of the spilled oil.

Comment: The statement in the Introduction that glaciers send icebergs floating out to sea is incorrect since they never reach the North Pacific.

Response: This discussion has been deleted from the Plan.

Comment: The plan's description of the "Chronology of the Spill" and the "Fate and Effects of the Spilled Oil" contained several inaccuracies and misleading or prejudicial statements.

Response: The "Introduction to the Plan" no longer contains a discussion of the chronology of the EVOS events or of the fate and effects of the spilled oil. The latter subject is treated, however, in A/W No. 6.

Comment: The Plan does not identify the study participants.

Response: The Trustees do not feel that the names of the participants are necessary in order to evaluate the quality of the studies.

Comment: Several comments stated that the PRP's were denied the opportunity to participate in developing the scope and design of the NRDA Plan and that the assessment should be jointly undertaken. Furthermore, limiting PRP's involvement to commenting on the Draft Plan is contrary to the natural resource damage assessment regulations. Other comments stated that PRP's should not be involved in the assessment process.

Response: The PRP's were given equal opportunity to comment with all interested parties in the damage assessment process. It is up to the Trustees to determine the extent of the involvement of the PRP's in the damage assessment process. This approach is consistent with 43 C.F.R. Section 11.32.

Comment: PRP's should be required to provide funding for experts and consultants to conduct an independent assessment and restoration plan.

Response: No such legal requirement exists under the CWA or CERCLA.

Comment: PRP's participation should be limited to providing financial assistance for the assessment.

Response: The level of PRP participation has been consistent with the damage assessment regulations and has been determined by the Trustees to be appropriate.

Comment: Exxon's studies should not be incorporated within the assessment. Exxon should not be given any part of the assessment to implement.

Response: At this time, Exxon's studies are not incorporated within the assessment process. However, if the Trustees determine such studies would be helpful and an agreement is reached with Exxon, the studies could become part of the process.

Comment: Only government employees were permitted to participate in the process. Knowledgeable industry scientists should have been included.

Response: Knowledgeable scientists from outside the government were consulted in connection with review of the studies. Many of these scientists are consulted by industry with respect to similar matters.

Comment: All traditional tribal governments should be Trustees and should be included in the process.

Response: Certain tribal governments may be considered Trustees under CERCLA. To ensure tribal interests were represented, a Bureau of Indian Affairs representative rendered advice during the assessment process for 1989 and the current plan. Efforts are currently underway to ensure tribal interests and concerns are being addressed in Economic Study #6.

Comment: Most of the studies were in the process of being conducted before public review of the Plan. Thus, the Draft Plan was an after-the-fact description of research already completed and limited the public's opportunity to comment. This procedure has made it difficult to determine cost-effectiveness and is contrary to the NRDA regulations at 43 C.F.R. Part 11.

Response: To determine effectively the effect of EVOS on natural resources, the Trustees determined that it was necessary to begin collection of data for studies as soon as possible, i.e., before the Draft Plan had been summarized, edited and published for review and comment. Such actions are consistent with 43 C.F.R. Section 11.22.

Comment: The injury determination and quantification phases are being conducted simultaneously, in violation of the DOI regulations. Failure to do pre-assessment screening caused unnecessary and expensive studies to be done of resources that probably were not injured by the spill; these studies should be discontinued, e.g., Fish/Shellfish Study No. 24, Marine Mammals studies relating to killer and humpback whales, and Air/Water Study No. 4. No further assessment costs (especially those relating to damages) should be undertaken until the Trustees have determined that "injury" has in fact occurred with respect to a particular resource. Nor should efforts toward quantification of non-injuries go forward.

Response: As stated earlier, use of the regulations is optional. However, a pre-assessment screen was conducted before proceeding with the process. All studies were reviewed and a determination was made by the Trustees whether to continue or modify them based upon data from the first year's studies.

Comment: The Plan should take into consideration views of the National Park Service since national park lands were affected by the spill.

Response: Views of the Park Service were, and continue to be, considered in the natural resource damage assessment process.

Comment: The Plan should make a formal effort to take advantage of the information that is being collected by outside persons.

Response: The Trustees are working on the creation of a public data repository to make available to the public scientific data collected by all parties.

Comment: The Plan fails to state what public review and comment will be considered in determining whether to continue studies after February of 1990.

Response: See current plan.

Comment: The plan should provide for the dissemination of data and results collected to private plaintiffs, and their outside experts, and other interested parties.

Response: The Trustees are currently considering the establishment of a public repository for data collected during this process. The public would have access to data in such a repository.

Comment: The public should have an additional right to comment once more specificity is presented.

Response: See current plan.

Comment: Prior public review and comment must be permitted during the development of study and restoration plans as well as the natural resource damage assessment, prior to decisions to terminate or change the scope or focus of study plans, and when settlement discussions with PRP's are initiated.

Response: The Trustees currently intend to provide public involvement throughout the assessment and restoration process. There is no requirement to involve the public if and when settlement negotiations are initiated.

Comment: If a study is aborted, its results should be released to the public.

Response: See earlier comments concerning the repository.

Comment: The Trustee Council should set up an independent scientific review committee exclusive of the state and federal experts.

Response: The Trustees have sought review by selected scientists and have carefully considered their comments on the study plans.

Comment: The Natural Resource Defense Council's experts should be incorporated within the peer review process.

Response: To the extent that NRDC's experts filed comments on the draft plan, they are involved in the damage assessment process.

Comment: The Trustees should allow the public to participate in the determination of whether the regulations will be followed in the damage assessment process.

Response: It is the Trustee's responsibility to manage all aspects of the assessment process, including the degree of public participation and use of the regulations. The public has and will continue to express opinions over the use of the regulations through the review and comment process, and those opinions will be carefully considered.

Comment: Because the potential risks of an oil spill were identified in an environmental impact statement, the State accepted this risk.

Response: The determination of liability or responsibility of particular parties is beyond the scope of the NRDA process. Further, without any identification of the environmental impact statement or the provisions referred to, it is impossible to respond to this comment.

Comment: The Trustees do not feel that they are obligated to follow the law because the Plan states that they have not decided whether, or to what extent, they will follow the Type-B damage assessment regulations.

Response: The Type B regulations are optional, and therefore there is no legal obligation to follow them. Nevertheless, the Trustees have followed a procedure that is generally consistent with the regulations.

Comment: Since the damage assessment process will kill marine organisms, an environmental impact statement must be done.

Response: An EIS is not required to conduct a natural resource damage assessment. However, the permitting requirements of applicable environmental laws have been complied with.

Comment: Restricting the damage assessment process to natural resources is inappropriate.

Response: The legal authority for the damage assessment limits claims to those involving injury to natural resources.

Comment: The development and amendment of the NRDA Plan is subject to the Administrative Procedures Act's rulemaking procedures and therefore must follow notice and comment procedures. The decisions to be made by the Trustees regarding whether to continue certain studies should be subject to public input. To provide meaningful public input, the Trustees should make available the results of all studies done last year, provide greater detail on studies proposed for 1990, and do so in a time frame which makes public comment meaningful.

Response: Even assuming, arguendo, that the conduct of the damage assessment is an administrative process subject to the APA, the development and amendment of a plan for that process does not constitute final agency action and is not reviewable under the APA or otherwise. Nevertheless, the Trustees have provided notice to the public of planned assessment activities and have solicited public comment on the assessment plan. The Trustees believe they have provided a reasonable period for the public to comment on the assessment. The Trustees have carefully considered these public comments in making decisions regarding assessment activities, including discontinuation or modification of studies. The Trustees agree that scientific data should be made available to the public by all parties, and have asked the PRP's to contribute to a public data center.

Comment: The Trustees have failed to provide the public with access to data collected, results of analyses and sufficiently detailed research plans. This violates the National Environmental Policy Act and the Administrative Procedures Act.

Response: There are no requirements under either the National Environmental Policy Act or the Administrative Procedures Act to make this information public. Nevertheless, the Trustees have made descriptions of studies available to the public, and are working to try to ensure that scientific data is also made public.

Comment: The damage assessment process may require compliance with

Section 106 of the National Historic Preservation Act. The Section 106 process requires that native corporations be permitted to participate as property owners and available parties in joint state/federal actions such as the studies undertaken in the Plan.

Response: Where required, damage assessment activities will proceed in compliance with Section 106 of the National Historic Preservation Act.

Comment: The principles and procedures of the DOI NRDA regulations have not been incorporated in the Damage Assessment Plan. It would be prudent to follow the regulations even if this is not required.

Response: The Trustees are considering use of the NRDA regulations on an issue-by-issue basis. The Trustees believe they have been acting in a manner generally consistent with the regulations.

Comment: The Trustees' actions regarding public participation in the damage assessment process contravene the provision of the DOI regulations regarding timing of public review and inclusion of public comment within the Plan.

Response: The NRDA regulations are optional, and the Trustees are under no legal obligation to follow the regulations. Nevertheless, the Trustees believe their actions are generally consistent with the public participation provisions of the NRDA regulations. In fact, the Trustees have provided a greater opportunity for public review and comment than is outlined in the regulations.

Comment: The damage determination studies, e.g. Economic Studies Nos. 1, 2 and 4, ignore both the premise that third parties whose commercial or property interests are impaired as a result of an oil spill may not pursue natural resource damage claims and the regulatory provision against double recovery.

Response: The Trustees are seeking recovery of damages to public interests, not private commercial interests. The economics studies will be conducted to avoid double recovery.

Comment: There is no legal support for the notion that possible loss of research activities or damages to archaeological sites are appropriate subjects for damage assessment.

Response: Archaeological and research activities are public uses of natural resources that may have been impaired by the oil spill. The Trustees are entitled to recover the value of any lost public uses of natural resources resulting from the spill.

Comment: The Plan's focus on direct human use values to determine injury is illegal. Under statute and case law, all lost services provided by natural resources must be assessed, regardless of whether the services lost benefitted humans directly, indirectly or benefitted the ecosystem as a whole.

Response: The damage assessment is directed to both loss in human uses and loss of services to the ecosystem.

COASTAL HABITAT

COASTAL HABITAT STUDY COMMENTS

Comment: The Coastal Habitat Injury Assessment should take into account impacts on Upper Cook Inlet and the west side of Cook Inlet.

Response: The study will assess injury to coastal habitats within the spill's primary impact area, which includes portions of Lower Cook Inlet.

Comment: The use of lightly oiled beaches in the study does not include the timing of such oiling as a parameter in determining the effect on the coastal ecosystem. In addition, several sites should be examined in greater detail.

Response: The Trustees have revised this study to focus on moderately and heavily oiled beaches. This decision eliminated lightly oiled sites from the study to allow for greater efforts in assessing potential biological impacts to coastal resources. The Trustees have adopted the recommendation that several sites be examined in greater detail.

Comment: Critical habitat sites for Stellar sea lions and harbor seals should be considered.

Response: During the winter of 1989-90, those responsible for the marine mammals studies, among others, were consulted to determine that the proposed coastal habitat sites adequately considered the habitat of these species. Further, since the coastal habitat study is based on a randomized design, adoption of particular sites is generally not appropriate, but extrapolation of results to these sites can be made.

Comment: The coastal habitat study should incorporate an evaluation of the fate of oil transported to the intertidal and supratidal zones and an assessment of the physical and chemical reactions of oil with the coastal sediments.

Response: The Trustees have added A/W No. 6 to the Plan to determine the fate of oil, including its persistence and toxicity in the intertidal and supratidal zones.

Comment: Fewer sites should be studied in greater detail in order to gain a more accurate picture of the extent of oil in the water column, sediment and organisms.

Response: The number of random study sites has been reduced and an increased emphasis will be placed on detailed analysis at selected sites in Prince William Sound.

Comment: The five representative habitat types that are incorporated into the study should be identified. Further, it is questionable whether data can be extrapolated to the entire spill area given the number of sites selected for study, the time period available for the study, and the rapidity with which significant changes in physical, chemical and biological variables may occur in the affected environment.

Response: The revised study plan identifies the representative habitat types incorporated into the study and contains greater detail regarding the methodology of each component of the study. The study is no longer limited to one year. As noted in the response to the preceding comment, the number of random study sites has been reduced.

Comment: Efforts should be concentrated on sites where historical data exists.

Response: Sites for which historical data exists have been incorporated into the study plan where feasible.

Comment: The study should consider the possible re-oiling of shorelines.

Response: Re-oiling of shorelines will be taken into account.

Comment: An effort should be made to coordinate the results of the coastal habitat study with other studies.

Response: The coastal habitat study was coordinated with other studies. The revised study plan reflects this coordination.

Comment: The effect of hydrocarbon on sediments and benthic species, such as kelp, should be studied, including any effects on fish and shellfish.

Response: The coastal habitat study will examine the species present at each site. The presence of benthic species, therefore, will vary from site to site as well as seasonally. Kelp beds will be studied. Tissue samples from fish and shellfish are being taken simultaneously with the hydrocarbon sediment samples so as to link the persistence and concentration of hydrocarbons in sediments to selected benthic, fish, and shellfish species.

Comment: The study description lacked sufficient detail regarding the collection of samples, the selection of the location for transects for each sampling site, the methods of extrapolating the study results to the entire spill-affected area, the linking of ecological effects to oil, and the analysis of data.

Response: The revised study plan describes in more detail the methods and procedures to be used to implement the study.

Comment: Contamination of organisms at levels below those of state and federal standards may be injurious and thus comparison of water column exposure to oil to these standards will produce information only about gross contamination. These standards should not be the bases for determining whether injury has occurred. All oil exposure should be documented.

Response: The exposure of organisms and plants to oil will be documented through plant and animal tissue analyses. All levels of hydrocarbon exposure will be documented.

Comment: The factors relied upon in developing a site selection and sampling strategy were not identified.

Response: Phase I of the revised study plan describes site selection methods.

Comment: The fifteen additional sites chosen for the study require reference sites.

Response: These study sites were added to provide a better picture of impacts at moderately/heavily oiled sites. Control (non-oiled) sites already existed for these new sites.

Comment: Information regarding resilience, resistance, stability and species diversity should be included in the coastal habitat study. Bioassays should be performed for species other than arthropods. In addition, acute and chronic toxicity for organisms from different trophic levels should be studied.

Response: The coastal habitat study is founded upon an ecosystem approach to determining injury. By examining biotic and abiotic links within the coastal habitat zones and by providing information to those responsible for other damage assessment studies, it is expected that a comprehensive, ecosystem-wide assessment of damages can be established. Bioassays on other invertebrates will be conducted in connection with A/W No. 6.

Comment: The proposed budget for the coastal habitat study is excessive given that the only feasible restoration strategy for coastal habitats is natural recovery.

Response: This study has been reviewed extensively by appropriate experts for design and cost-effectiveness and, where appropriate, has been revised accordingly. Further, it has been coordinated with other studies to ensure integration of collection methods and study results. The budget for damage assessment reflects the costs of work designed to determine the injury to coastal habitats resulting from the Exxon Valdez oil spill, not efforts to restore damaged habitats.

Comment: The period over which samples will be taken is not given, but representative samples should be revisited on an annual basis for several years and then periodic revisitation should be carried out for at least a decade.

Response: Coastal habitat data collection is scheduled to be conducted over a three-year period, which commenced in 1989.

Several samplings per year are being collected to assess potential injuries and recolonization rates by intertidal and supratidal flora and fauna.

Comment: Plants and algae should be censused and analyzed for hydrocarbon content.

Response: Vegetation from the supratidal zone and algae from the intertidal and shallow subtidal zones will be assessed for acute and chronic effects both through hydrocarbon contact and uptake.

Comment: An estimate of community function in coastal habitats should be made. Primary and secondary productivity should be assessed in the intertidal and nearshore water column and benthos. Benthic community respiration rates might produce useful information regarding impacted and control habitat function.

Response: Due to the extent of the spill-affected area and the study's primary objective (to estimate the quantity, quality, and composition of critical trophic levels in moderate-heavily oiled sites relative to non-oiled sites), an estimate of community function cannot be directly determined. The study, however, does take an integrated ecosystem approach to assessing the interrelationships between and within supra-, inter-, and shallow subtidal plants and animals.

Comment: It is unlikely, with so many sites and so short a time frame for study, that the data gathered can be extrapolated to the entire spill-affected area. Large and rapid seasonal changes in physical, biological and chemical variables constrain the sampling program.

Response: The current time frame for the study is three years and it is anticipated that this period of time will be sufficient to gather the necessary data for a complete extrapolation of impacts.

Comment: Without seasonal, annual, or pre-spill data, it is not possible to determine whether changes in critical trophic levels and interactions are oil-based.

Response: Seasonal and annual data has been integrated into the study design. However, pre-spill data is limited, and a parred comparison design of oiled and non-oiled study sites has been developed to measure critical plant and animal population changes.

Comment: A more comprehensive plan is needed for assessing the physical/chemical interactions of oil with the coastal sediments.

Response: See A/W Study #2.

Comment: The spatial resolution of the four vertical transects per site is not specified. Nor is any information given regarding how many of each type of measurement is to be made or the methods to be used.

Response: The details of transect design and randomized quadrate sampling along each transect are specified in the description of methods to be used to implement the study, which appear in the revised study plan.

Comment: The coastal habitat study does not describe any of the forty-five categories to be studied.

Response: The 1990 study plan contains this information.

Comment: The coastal habitat study needs to address algae, phytoplankton, zooplankton, microbiota and other organisms at the bottom of the food chain, but does not indicate at which trophic levels toxicity will be examined.

Response: Only algae and higher level organisms and plants are included in the coastal habitat study. Microbiota and other organisms are being examined in the Air/Water studies.

Comment: The mere fact that shorelines were oiled should be considered an injury in the coastal habitat studies.

Response: To the extent that oiling of shorelines has diminished economic, biological or intrinsic value of these resources, the impact is accounted for in the economic studies.

AIR/WATER

AIR AND WATER STUDIES COMMENTS

Comment: Information from these studies should be coordinated with coastal habitat studies and economic studies as well as the restoration plan.

Response: Air/Water studies support the information needs of a wide variety of NRDA studies, including those mentioned.

Comment: The Air/Water studies should examine continuing air emissions resulting from lingering oil, treatment or restoration activities.

Response: A/W study No. 5 was discontinued last summer because air quality had returned to normal.

Comment: Hydrocarbon analysis should go beyond determination of whether water quality criteria have been violated.

Response: Hydrocarbon analysis will not be limited to measuring water quality. Ocean bottom and beach sediment samples and samples taken from various biological communities will be taken and analyzed to determine if hydrocarbon contamination has occurred.

Comment: Plots and wildlife density studies of benthos should be used in the A/W studies.

Response: The type of study suggested is being conducted as a portion of A/W study No. 2. A portion of this study will involve documenting changes in the structure of biological communities in ocean bottom sediments.

Comment: A sampling program should be used for sediments, particularly those at more than 15 meters in depth, that would address the number of species present, the number of specimens of each species, the proportion that each species bears to total faunal density, oxygen content at the sediment-water interface and interstitial water, and the depth of the redox discontinuity layer using screen meshes of .3 mm or less.

Response: A/W study No. 2 does provide for infauna sampling of marine sediments in deep water. Species composition and hydrocarbon presence will be the main parameters documented.

Comment: The Air/Water study program did not take into consideration that the only feasible restoration of air/water resources beyond immediate shoreline cleanup is natural recovery.

Response: The Air/Water studies are designed to document resource injury in a large and complex ecosystem.

Comment: The lack of focus of A/W study No. 2 on the quantity of oil in sediment or intertidal areas and the focus of A/W No. 1 on quantities of floating oil would make it difficult to create an integrated model over time of the extent of oiling.

Response: The quantity of oil in supratidal and intertidal areas is being documented by the C/H study. A/W study No. 1 will be discontinued in 1990 as little free floating oil is expected this year.

Comment: The Air/Water studies should be used to create an integrated model of the fate of the oil and these should be internally consistent, i.e., focus on the same parameters (quantity, volume, concentration, distribution, persistence, composition, time).

Response: A/W study No. 6 is a new study designed to produce a "mass balance" or budget for the fate of the oil from EVOS.

Comment: It is not possible to discern whether these studies are necessary because there is no data in the Plan indicating whether spilled oil may have affected the marine environment below the upper level of the water column.

Response: At the time the plan was written, this data was not available. Such effects were considered likely based on the data provided by previous spills.

Comment: Air/Water studies focus on human use, rather than all, values. Presence of oil should be documented at all levels of the ecosystem rather than just valued resource species.

Response: The levels of oil found in the environment and its effects will be assessed for a wide range of natural resources and their habitats.

Comment: The Air/Water studies should include projects that would evaluate petroleum hydrocarbon persistence in intertidal and supratidal sediments.

Response: Both A/W study No. 2 and the C/H study, as well as others, address this issue.

Comment: The Plan does not consider effects on phytoplankton or zooplankton or marine bacteria in the water column or sediments. Nor does it consider marine plants which are important to the food chain.

Response: Phytoplankton and zooplankton were not studied per se. However, marine bacteria in sediments, as well as benthic algae and higher plants are being addressed in A/W study No. 2 and the C/H study.

Comment: Oil spill trajectory models are not accurate for use in Air/Water studies.

Response: The selection of oiled and non-oiled locations for the conduct of sampling for these studies was based on direct observations of the presence or absence of oil.

Comment: Air/Water studies should examine the effects of dry flux of organic air pollutants on vegetation eaten by foragers and the long-term chemical changes in water affected by the spill, including effects on global and regional water chemistry.

Response: The Air/Water studies were designed to measure these types of impacts and their effects.

Comment: Water samples collected at depths of 15 meters and greater should be the emphasis of a monitoring program of oil-contaminated sediment stations. Oxygen content at the sediment-water interface and in the interstitial water of the sediment should be measured, and determinations of the depth of the redox discontinuity layer in the sediment that separates the upper oxygenated from the lower anoxic sulfide sediment should be made.

Response: The type of study suggested is being conducted as a portion of A/W study No. 2. A portion of this study will involve documenting changes in the structure of biological communities in ocean sediments. Species composition and hydrocarbon presence will be the main parameters measured.

Comment: The methods for Air/Water studies are questionable because satellite imagery is worthless for tracking oil. There is no method mentioned for tracking less concentrated and subsurface oil.

Response: The methods used to measure hydrocarbon presence in the water column and marine sediments are very sensitive. The determination of what is an oiled or non-oiled area for the purposes of these studies was made based on direct observations.

Comment: To the extent that the Air/Water studies focus on federal/state water quality standards as a measure of injury, they do not account for effects on other than human species.

Response: A number of marine species are being examined under NRDA studies to determine if they have been injured as a result of the EVOS.

Comment: The Air/Water studies fail to recognize that the only feasible restoration of air and water resources beyond cleanup activities is natural recovery. This program of studying air and water resource damages is excessive and costly. It also fails to specify methodologies to be used.

Response: The marine habitats examined under the Air/Water studies are very large and support large biological communities. To ignore this portion of the environment in the NRDA studies would leave a large gap in oil spill impact documentation. The methodologies to be employed in their studies are described in the current plan.

Comment: The discussion of fate and effects of spilled oil is over-simplified and is therefore inadequate.

Response: A/W studies have been modified in the current plan to provide more information on fate and effects of spilled oil.

Comment: The Plan needs detailed studies of changes in microbial diversity, including changes in mocrobial populations at the spill site and examination of the influence of oil on this diversity.

Response: The A/W #2 has been modified to allow for examination of microbial populations at a variety of locations and depths in PWS.

Air/Water Study No.1

Comment: A/W study No. 1 does not identify which oil spill models will be used. Field studies should be done to provide information regarding detailed circulation pattern(s).

Response: A/W study No. 1 mapped the distribution of oil on the water as determined by visual observations and does not involve modeling. A mass/balance model will be prepared as part of the new A/W study No. 6. See 1990 study plan for details.

Comment: A/W study Nos. 1 and 2 should consider the effects of oiled infauna of intertidal and subtidal habitats on the grey whale.

Response: Grey whales found dead within oiled areas have been, and will continue to be, closely examined for evidence of oil contamination if their condition is suitable.

Air/Water Study No. 2

Comment: The cost of A/W study No. 2 is too high given the information it will provide. There is insufficient information provided regarding the method to be used while visually checking for oil in bottom sediments; this method is subject to bias. Nor is there any information given regarding the coordination of near-shore and intertidal sampling sites. Use of a manned submersible is an ineffective and costly means of checking for oil in bottom sediments. Neither geographic nor temporal trends between sediment samples can be determined from the Plan. The plan does not indicate how TOC or grain size analyses will be conducted or how the samples on which they are to be conducted will be chosen.

Response: The benthic habitat areas involved with the spill are very large and support important biological communities. The current location of a significant portion of the oil still present in marine ecosystems may be found on or in bottom sediments where many organisms live and feed. To ignore this portion of the environment in NRDA studies would leave a large gap in oil impact documentation. The sampling of intertidal and subtidal sediments are coordinated between A/W study No. 2 and the C/H study. Standard sampling techniques will be employed. Although a manned submersible was used to conduct some limited surveillance and sampling in 1989, it is not part of the 1990 study plan. Visual observations of oil in bottom sediments cannot be relied on to document their presence. Chemical methods will be employed to determine if hydrocarbon contamination is present. The large scale sampling planned requires the use of standard sampling techniques.

Comment: A/W study No. 2 should collect water/sediments from depths greater than 2 cm to determine how oil has become incorporated in sediments.

Response: Depths greater than 2 centimeters are being sampled under A/W study No. 2.

Comment: A/W study No. 2 should be coordinated with the remaining Air/Water studies as well as the marine/mammal studies to ensure that secondary impacts on marine mammals will be assessed.

Response: The Air/Water studies are being closely coordinated among themselves and with other NRDA studies that depend on them.

Comment: A/W study No. 2 should be coordinated with marine/mammal studies to insure that food chain effects on marine mammals can be measured.

Response: The purpose of this study is to estimate hydrocarbon concentrations in nearshore water at sites where marine mammal prey may be located. The study has been reviewed by the persons conducting the Marine/Mammal studies.

Comment: A/W study No. 2 should include sites within CI, especially the west side.

Response: In 1989, NOAA sampled five sites in CI, particularly on the west side of the Inlet. Based on the results from these samples, the Trustees have determined that further sampling in that area is not warranted.

Comment: A/W study No. 2 does not indicate the number of samples to be analyzed. If the results will be used to support the C/H study, the same sampling and chemical methods should be used.

Response: Although studies that are sampling very different types of environmental parameters may have to use different analytical procedures, the basic methodologies for collecting samples and analyzing samples to detect hydrocarbon presence have been standardized. These procedures are documented in technical plans that guide the activities of all damage assessment projects. The T/S No. 1 project provides for control and standardization of all hydrocarbon sampling and analyses conducted under damage assessment programs.

Comment: Measurement of hydrocarbon compounds in pore waters in A/W study No. 2 would permit a better estimate to be made of what is available to biota and what may easily be remobilized from sediment. Laboratory exercises on sediment samples would generate data on the actual flux of hydrocarbons out of the sediment and its bio-availability to marine organisms.

Response: While the scientific literature indicates that bioavailable fractions of complex contaminant mixtures may be mobilized through solution into pore water, the scope of the program to obtain large amounts of interstitial water needed for accurate determination of petroleum hydrocarbons makes such an approach impractical in these studies. However, a limited number of interstitial water samples will be taken and analyzed in 1990.

Comments: A/W study No. 2 will only be able to guess at oil spill movement since data from A/W study No. 1 will not have been analyzed.

Response: The selection of oiled and non-oiled sites for sampling under this study was based on the direct observation of the presence or absence of oil.

Comment: The study does not provide a method for distinguishing differences in sediment oiling that are due to geographic variation from those due to temporal variation, thus preventing determination of geographic or temporal trends.

Response: The primary objectives of this study require that resampling occur to detect changes in hydrocarbon contamination levels and in benthic community structure. This resampling to determine changes over time and the use of non-oiled control sites will allow an evaluation of the fate of oil as it relates to benthic habitats in marine sediments.

Comment: The study should be expanded to examine grey whale feeding areas, with biopsies of grey whales migrating through or residing in those areas.

Response: The Trustees are not aware of any generally recognized grey whale feeding areas near locations of high oil contamination. Grey whales found dead within oil affected areas have been, and will continue to be, closely examined for evidence of oil contamination.

Comment: A variety of depths of sediments should be collected to determine how oil has been incorporated into sediments.

Response: A variety of depths was sampled in 1989 and will be sampled during the 1990 field season to ensure that the fate of the oil as it relates to marine sediments is documented.

Air/Water Study No. 3

Comment: The length of time for the caged mussel study, the depth of deployment, whether the same compounds would be analyzed as in water column studies, the number of replicates per cage and the number of stations used for the caged mussel study is questionable.

Response: The field experience gained in 1989, combined with biometric support for the study design, were used to develop the 1990 study plan for this project.

Comment: Sampling depths should have been selected on the basis of physical (i.e., pynocline depths) or biological (i.e., euphotic) factors.

Response: Standard depths for the bioaccumulator and sediment trap sampling in this program were selected as the best means to maintain comparability. The use of physical, biological or other factors to determine sampling depths would result in a highly varied sampling pattern among different locations.

Comment: Why were only areas west of PWS being considered?

Response: Areas to the east of PWS had no documentation of oil presence during the extensive oil location surveys conducted in 1989. Current patterns in the area make it unlikely that oil would drift to the east of the Sound. In order to cover adequately areas of known impact, areas to the east of the PWS were not included in the study plan.

Comment: Oil particulates could foul baleen plates of whales, and this study should be coordinated with marine/mammal studies to insure that information necessary for those studies is collected.

Response: Baleen whales are not being sacrificed under marine mammal studies. Any dead whales found are closely examined for oil contamination.

Comment: A/W study No. 3 does not specify the methods to be used to sample water at various depths. Precautions should be taken to avoid contamination of the samples from surface slicks, sheens and vapor-phase hydrocarbons.

Response: The standard sampling procedures contained in the Quality Assurance Program ensure that samples will be protected from contamination.

Comment: In A/W study No. 3, the use of mussel cages is of little value more than a few weeks after a spill because hydrocarbons concentrations are low. The statistical design of the testing methods is necessary. Use of the source of experimental mussels in Southeast Alaska as control sites is improper. The variability of oil in the mussels before exposure to Sound waters needs to be known.

Response: The use of mussels as bioaccumulators is designed to allow the detection of highly diluted levels of oil contamination in the water column. Samples of mussels from Southeast Alaska were used as control as any samples from areas potentially affected by the spill may have been exposed to oil contamination. Information on the concentration of hydrocarbons in PWS mussels prior to the EVOS is available.

Comment: There is no indication in this study how bioaccumulation data will be interpreted.

Response: The levels of hydrocarbons that can cause immediate or delayed effects in certain organisms are known from studies that were conducted prior to the spill. If the study finds similar levels traceable to the EVOS, in waters these organisms are exposed to, this will indicate that the organisms are being injured.

Comment: A/W study No. 3 utilizes an inappropriate water quality standard (10 ug/liter).

Response: Water quality data will be evaluated to determine whether all applicable water quality standards are met. This is consistent with the NRDA regulations for determining injury to water resources. The Trustees do not believe it is appropriate to conduct an ad hoc review of the criteria in the context of the damage assessment.

Comment: Very large samples are needed to make the results of A/W study No. 3 accurate. Dissolved and particulate fractions need to be analyzed separately because of their high partition coefficients. This study ignores the sea surface microlayer of the water column, which is a location for locally high concentrations of hydrocarbons.

Response: The use of bioaccumulators in the form of mussels will be employed to document oil presence rather than to attempt to increase greatly the water sample size. Particulate concentrations will be sampled in nearshore waters and dissolved fractions will be sampled over a range of depths, locations and times.

Comment: There is no information in A/W study No. 3 regarding how long the mussel cages will be deployed and at what depths and how many replicate clams per cage. The sea surface should be studied. Placing cages at so many stations may be unnecessary.

Response: Although the seasurface layer will not be specifically sampled under this study, shallow location of mussel cages will occur.

Comment: The sampling depths for A/W study No. 3 should have been based on physical or biological factors.

Response: Standard depths for the bioaccumulator and sediment trap sampling in this program were selected as the best means to maintain comparability. The use of physical, biological or other factors to determine sampling depths would result in a highly varied sampling pattern among different locations.

Comment: A/W study No. 3 should take into account the facts that dissolved and particulate hydrocarbon compounds in the water column may affect the distribution, abundance, and productivity of vertebrate and invertebrate species on which seals and whales thrive and that particulates may interfere with the filtering plates of the baleen whales or be ingested.

Response: Any dead whales found in the spill area are being closely examined for effects of oil. Marine Mammal studies will document any occurrence of displacement of whales in PWS.

Air/Water Study No. 4

Comment: A/W study No. 4 will study benthic infauna in depths of 20 meters or more even though it is very unlikely that oil will have precipitated in significant amounts to that level. This is an unnecessary cost.

Response: The benthic habitats of the areas affected by the spill are large and support many important organisms. To ignore this portion of the environment in damage assessment studies would leave a large gap in oil impact documentation.

Comment: A/W study No. 4 should investigate infaunal organisms and sediments. This study fails to indicate the number of grabs per station or frequency of sampling. Organisms should be evaluated for hydrocarbon content.

Response: This study is incorporated into A/W study No. 2 in the 1990 plan and the combined studies will include sampling for infaunal organisms and for sediments. A detailed description of techniques is included in the 1990 study plan. The organisms sampled will be analyzed for hydrocarbon content.

Comment: The minimal and isolated effects on deepwater benthic resources does not justify the cost of the A/W study No. 4. There is no description of the sampling, experimental and analytical methods to be used in this study. Nor is the type and magnitude of change in the resources that will be used to define injury identified. There is no mention of how the stations will be compared. There is no specification of how petroleum concentration and composition, water depth, sediment grain size, sediment total organic carbon or other factors will be accounted for in determining whether changes in community structure are linked to oil.

Response: Experience with other spills indicates that a possibility of injury to benthic resources exists. As these resources are extensive within the spill area, it would not be in the public interest to ignore the potential for injury. See 1990 plan.

FISH/SHELLFISH

FISH/SHELLFISH GENERAL COMMENTS

Comment: The 26 Fish/Shellfish studies are generally inadequate for predicting long-term effects on populations; they are better suited for estimating the short-term and acute effects of the spill.

Response: The Fish/Shellfish studies are designed to evaluate both short- and long-term effects of the oil spill. Short-term effects such as mortality to a specific life history phase (e.g. egg, larvae, fry, adults) are being documented and quantified. Long-term effects are being evaluated using parameters such as decreased growth, decreased reproductive potential, decreased abundance, and increased incidence of developmental defects and disease.

Comment: Studies should continue for more than one year.

Response: Sixteen of the 26 Fish/Shellfish studies that were initiated in 1989 to assess impacts of the EVOS have been continued in 1990 and will be evaluated in the winter of 1990-91 for possible continuation in 1991.

Comment: Portions of studies 1-4 should be continued to document recapture of tagged fish.

Response: Studies 1-4 were being continued for 1990. The recovery of coded-wire tagged fish was a primary consideration for continuing studies 1, 3, and 4.

Comment: The number of sites studied in studies 1-4 and 7-9 seems excessive.

Response: All studies were reviewed during the fall and winter. As a result, some studies were modified to ensure a statistically valid design. Therefore, the number of study sites in studies 1-4, and 7 and 8 are justified and will continue. Study No. 9 was not continued.

Comment: Streams in either the eastern or Kamishak districts should be studied in studies 7, 8, 9 and 10.

Response: The selection of sites for studies 7, 8, 9 and 10 was made to provide an experimental design of paired comparisons to detect the impacts of oil on study species. Assessment of populations to detect changes in the productivity of fisheries associated with the result of the paired comparisons was based on different "study areas," either "oiled" or "non-oiled," or on different "study times" when there was historical data available on "oiled" populations of fish.

Comment: The Fish/Shellfish studies should evaluate ecosystem and food chain impacts. Fish food webs should be studied before and after the spill in conjunction with toxicity and habitat studies.

Response: While the individual studies primarily focus on impacts to individual species, it is anticipated that analysis and synthesis of the results of all NRDA studies (e.g. coastal habitat studies, air/water studies, fishery studies, bird studies, marine mammal studies, and terrestrial mammal studies) will provide an assessment of ecosystem and food chain impacts.

Comment: Additional testing is needed both within and outside of PWS, including a consideration of additional sites and varying concentrations of oil.

Response: All studies were reviewed during the fall and winter to ensure that they would produce statistically valid results. This review included an evaluation of the number of sites and extent of oiling. Based on this review, studies were modified where necessary to ensure statistically valid design.

Comment: Samples should be collected at least in triplicate to allow for estimation of variance at sites.

Response: Some projects are collecting samples in triplicate and other projects have been reviewed with this comment in mind.

Comment: Analysis of variance (ANOVA) is overused and is inappropriate for an analysis of sigmoidal relationships of toxicity curves or skewed bell shape of habitat preference curves. Consideration should be given to the use of non-parametric and multi-variate statistics. Data pertinent to food chain and ecosystem impacts should be analyzed using loop analysis.

Response: A biometrician has been assigned to each Fish/Shellfish study. An important component of his or her duties will be to investigate the appropriateness of any statistical test mentioned in the study plans. Underlying assumptions will be tested and alternative analyses will be considered.

Comment: The methods used for hydrocarbon testing may underestimate contamination; numerous (i.e., more than 15) samples of each age/size class to allow better regressions and avoid composite sampling is suggested.

Response: Sample sizes for hydrocarbon testing were not established solely to minimize a variance associated with an estimate of hydrocarbon presence. Collection goals of all projects were reviewed to meet multiple objectives, including timely sample processing and result reporting.

Comment: Studies should go beyond Unimak Island and in the west and east of PWS.

Response: The Fish/Shellfish studies do not go beyond Unimak Island in the west and east of PWS because all information received to date suggests that beyond these areas there has been little or no impacts from the EVOS.

Comment: No study evaluates impacts to primary and secondary productivity in impacted waters, particularly impacts to marine plants.

Response: Impacts to primary and secondary production (marine plants) are being studied by investigators in the Coastal Habitat study.

Comment: Many of the Fish/Shellfish studies go beyond what is necessary to identify and quantify damage and are, in essence, research programs to expand knowledge on the ecology and fisheries of PWS and adjacent waters.

Response: The Fish/Shellfish studies are specifically designed to identify and quantify adverse effects of the EVOS and identify appropriate measures for restoration. Each study undergoes an intensive annual review and approval process by professionals in multiple state and federal agencies. Scientific and technical peer reviews are conducted which provide ongoing input on objectives, methods, and analyses to the principal investigators for each study. The plans for these studies are also distributed for review and comments by the general public and the comments responded to. This process ensures that the studies are necessary and appropriate damage assessment studies.

Comment: The types of injuries to fish and shellfish being studied are inadequate because the studies almost totally ignore sublethal impacts on fish such as long-term changes in survival and reproduction, contaminant body burdens.

Response: Sublethal impacts to fish and shellfish from oil are being studied, receiving more attention during the second year of study. Parameters for sublethal impacts that are being evaluated include: (1) the presence of hydrocarbon metabolizing enzymes; (2) the interaction of metabolites with subcellular structures; (3) genetic abnormalities; (4) gross morphological abnormalities; (5) histopathological effects; and (6) physiological effects of exposure to oil from the Exxon Valdez.

Comment: The public review document indicates a lack of coordination between Fish/Shellfish injury assessment studies, economic value studies and restoration planning.

Response: Over the winter of 1989-90, the Trustees prioritized coordination among the various natural resource damage assessment investigators, economic investigators, and restoration planners to discuss preliminary results and plan for the continuation of studies. Study plans and results from the Fish/Shellfish studies have been made available for economic value studies, restoration planning groups, and the other study groups.

Comment: The fish studies given inadequate attention to prey species of principally studied fish.

Response: Species were selected for study based on their value as indicators of injury, their role as key species within the ecosystem, or their direct importance to man as components of subsistence, commercial, or sport harvest. Juvenile salmon and herring are considered two of the most important prey species for piscivorous fishes in the spill-affected area and are being studied intensively.

Comment: Fish studies 3, 4 and 9 would benefit from laboratory studies that could control marine variables, such as natural predation and mortality at sea.

Response: The addition of controlled laboratory experiments that could be conducted in conjunction with F/S studies 3, 4 and 9 has been considered. The Trustees believe that because of convincing evidence found during 1989 regarding reduced growth of fry exposed to contaminated water, it was important to continue to quantify impacts on the growth of unconfined fry residing in Prince William Sound. Studies at the Auke Bay lab have shown that growth is significantly reduced in fry exposed to water-soluble hydrocarbon; however, these results need to be confirmed for fry living in natural conditions.

Comment: Studies 1, 2, 7 and 8 would benefit from laboratory studies to support the impact on eggs and fry.

Response: The Trustees believe it is most important at this time to investigate possible impacts to eggs and fry in their natural environment.

Comment: The thrust of most of the Fish/Shellfish studies is to determine the impact to commercial fisherman which is not compensable under NRDA. Any remaining damages would be quite small and the study costs therefore may not be recoverable. The study ignores those species that appear to have only intrinsic values, such as fish that are important prey species.

Response: These studies are designed to identify and quantify injury to public resources from the EVOS and identify appropriate measures for restoration. Some of these fish and shellfish have commercial value. Others have value for their contribution to sport, subsistence, and/or personal use fisheries. In addition, these fish and shellfish populations form integral parts of a vast and complex ecosystem which also includes various other invertebrate species (e.g. birds and mammals). For example, the various life history stages of Pacific herring are an important forage species for various piscivorous fishes (e.g. Pacific salmon, halibut, pollock, sablefish, cod, squid, and flatfish), birds (cormorants, gulls, mergansers, heron, eagles, loons, and kingfishers), mammals (sea lions, seals, porpoises, whales, bears, and humans), and invertebrates (crabs). All of the species selected for study have a value to the ecology of the area, which goes beyond their value to a particular sport or commercial fishery. The budgets of these studies are scrutinized very closely and any costs that are deemed excessive are either reduced to reasonable levels or are eliminated.

Comment: The study descriptions do not provide details of methods being used. Therefore, it is impossible to determine whether standard and accepted methods are used, possible biases are accounted for, and representative sites are sampled, and results will be statistically valid. The descriptions do not provide the statistical basis for comparing abundance levels and provide no methods to differentiate natural phenomena from spill effects.

Response: The 1990 study plans for Fish/Shellfish studies provide more detailed descriptions of methods, sample sizes, sampling sites, and statistical techniques that are being employed in each study.

Comment: Salmon are unlikely to have been adversely affected by hydrocarbons at concentrations that were documented in the water column and it is extremely unlikely that any long-term impacts on salmon stocks attributable to the spill can be documented.

Response: Such statements are premature and judgment will be reserved until the results of the studies are known.

Comment: The Plan should contain a study similar to Fish/Shellfish Study No. 19 for the fish larvae that were oiled as a result of the oil's movement through Shelikof Strait and other areas of the Gulf of Alaska.

Response: It is anticipated that results from F/S #19 can be used to evaluate injury in other areas.

Comment: The number of angler days identified in the introductory section of the F/S studies (p. 48) does not comport with that identified in F/S study No. 6.

Response: F/S study No. 7 has been discontinued. Hence there is no longer a description of this study in the Plan. The number of angler days identified in the introduction for these studies has been reconfirmed.

FISH/SHELLFISH STUDY NO. 1

Comment: Historical data must be corrected to take into account factors such as timing, climate, harvest, recruitment, and water levels.

Response: The detailed analysis of historical data to assess the extent of damage due to the oil spill will be done in F/S study No. 28. Variations in migratory timing, harvest, and recruitment will be accounted for in that run reconstruction process.

Comment: Assessment of the damage due to loss of habitat should be estimated annually at least until the progeny of 1989's spawners return, i.e., approximately 1994.

Response: The studies will be reviewed during the winter of 1990-91 for possible continuation. F/S studies Nos. 1, 2, and 3 were designed so that they could be continued through the return years for adults originating from the 1989 brood year.

Comment: There should be microhabitat studies to determine whether mating females avoid lightly oiled areas or are less effective in mating redds in oiled areas.

Response: A detailed microhabitat study to determine the effects of oil contamination on redd site selection in salmon is beyond the scope of F/S study No. 1. However, this study will provide an estimate of numbers of fish spawning in oiled streams for comparison with historic data.

Comment: Suitable control sites may not exist in PWS; since salmon are highly mobile and have keen olfactory senses, there may be avoidance for the general area.

Response: It is possible that migratory patterns for all stocks in the Sound may have been affected but presumably effects at this level would be Sound-wide and would apply equally to all stocks. In that case, differential survival between stock from oiled versus non-oiled streams should still be detectible. The impact of possible Sound-wide avoidance should be detectable from an evaluation of pre-spill data.

Comment: Sublethal effects of oil, such as confusion of olfactory senses and reproductive impacts on adult spawners should be studied.

Response: These studies are not within the scope of this particular project. The results of other studies investigating such sublethal effects will be considered in evaluating the data from this study.

Comment: The linkage between the oil spill and sockeye salmon spawning habitats is unclear since they are not known to spawn intertidally.

Response: While this study does include evaluation of impacts to sockeye salmon in the objectives, because pink and chum salmon are numerically far superior in the PWS, they are accorded much more attention in the study. As much as 75% of the pink and chum salmon spawning in PWS is intertidal. Therefore there is good reason to investigate effects on eggs and fry in the intertidal areas contaminated by oil. Sockeye salmon do not spawn intertidally but the smolt spend much time in nearshore estuarine areas adjacent to spawning streams and might be affected adversely by contamination. Closures of fisheries targeted on sockeye salmon may also result in larger than desired escapements. Subsequent fry production may exceed the carrying capacity of the fresh-water rearing area, leading to poor smolt production and fewer returning adults in subsequent years.

Comment: Given the number of variables potentially affecting this population, such as fishing pressure changes, all assumptions made must be clearly specified in the course of assessing results.

Response: The reviewer is correct. Fish populations experience a great deal of natural variability that must be documented and accounted for in the experimental design and data analysis. The study has been carefully designed to incorporate streams which have an extensive historical data base to document natural variability.

Comment: This study fails to improve and catalog baseline information on productivity of PWS salmon streams, which will result in an underestimation of the value of the resource.

Response: This study was designed to incorporate only streams for which there is an extensive historic data base. The study will greatly improve the ground survey data base for 138 streams and results from the ground surveys will also help in the re-evaluation of 30 years of historic escapement data from 211 streams included in the ongoing ADF&G aerial survey program.

Comment: There is no identification of "aerially surveyed index streams." If they are to be used determining salmon abundance, the length of time over which they have been surveyed should be studied.

Response: ADF&G conducts a systematic weekly survey of 211 salmon spawning streams in PWS using a fixed-wing aircraft flying at slow speed and low altitude (aerial survey) to estimate the number of fish present in each stream. Estimates of weekly abundance for aerial counts can be used to estimate the actual spawning population (escapement). These estimates accurately reflect relative differences in abundance between streams and between years within a stream. We refer to this relative measure of abundance as an "index" of abundance and we refer to the streams included in the program as "index streams." Our weekly aerial survey program has been consistently conducted on the same 211 index streams for more than 30 years.

FISH/SHELLFISH STUDY NO. 2

Comment: Controlled laboratory studies should be considered for examination of the over-winter mortality of eggs and pre-emergent fry.

Response: In fact, many such studies have been done. The FRED Division of ADF&G has done many studies on the over-winter mortality studies on pink and chum salmon eggs incubated in a variety of conditions. The NMFS has also done an exhaustive series of experiments which document increased mortality in pink and chum salmon eggs when incubated in the presence of various hydrocarbon compounds at various dosages. Results from these studies will be considered in analyzing the data generated from F/S study No. 2.

Comment: If impacts are detected as a result of the analysis of hydrocarbon content in alevins, there should be an assessment of what these results will mean to future generations.

Response: The results of this study will be integrated with the results from F/S studies Nos. 1 and 2 to assess total loss of future production in PWS. This analysis will be completed as part of the new F/S study No. 28.

Comment: The relevance of this study for determining the impact of the oil spill is questionable because it is physically impossible for oil spilled in PWS to travel up current in a fresh water stream. Abundance and over-winter mortality for these species in inter-tidal areas cannot be extrapolated from the fresh water areas proposed for study in this project.

Response: The confusion here may lie in the fact that ADF&G refers to the egg and alevin (pre-emergent fry) states of pink and chum salmon life history as the "freshwater" portion. In fact, between 50% and 75% of the pink and chum salmon spawning in PWS occurs in the intertidal area. Sampling at each stream in this study occurs at three intertidal levels (1.8 m - 2.4 m, 2.4 m - 3.0 m and, 3.0 m - 3.7 m above mean low water). There is also one sample transect above tidal influence on each stream. The latter site is sampled for consistency with the historical data base and for comparison with stream variability not associated with oil contamination.

Comment: This study emphasizes coverage of a maximum number of streams rather than more complete documentation at fewer streams.

Response: The study actually emphasizes coverage of a maximum number of streams as well as complete coverage within streams. Maximizing the number of streams is important because of the variability between streams. There has been an attempt to reduce the effects of this variability in this study by incorporating a large number of streams. It is true that larger sample sizes within each stream would increase the precision of our estimates. Unfortunately, larger sample sizes could also make a significant impact on fry production in the streams. They would also require additional sampling time within each stream and lead to a reduction in the number of streams that could be sampled. The current sample sizes are a compromise that provides the necessary level of precision.

Comment: The location and duration of sampling are not described, and are potential sources of sampling error.

Response: Egg deposition sampling on 30 streams takes approximately two weeks at the end of September. Pre-emergent fry sampling on the same streams also requires about two weeks and takes place in late March. Each sample transect requires approximately one hour to complete and each stream requires approximately four hours to complete. Depending on the tides and hours of daylight, two or two and one-half streams can be sampled per day. The sampling error associated with sampling spread over this interval is not significant.

Comment: This study is completely research-orientated rather than a damage assessment-orientated.

Response: The study is designed to document reductions in survival of salmon eggs and pre-emergent fry as a result of oil contamination in the intertidal spawning areas of PWS and as such is an appropriate damage assessment study.

Comment: Two replicates of pre-emergent fry sampling is inadequate and sampling twice in April does not constitute replicate sampling with respect to pre-emergent fry.

Response: The term replicate may have caused confusion. Duplicate sampling was conducted in 1989 to look for gross differences in mortality prior to and immediately after the spill at contaminated streams.

Comment: More sites per stream should be sampled, and the sample design shows a significant potential for bias.

Response: The statistical design has been reviewed and adjustments made where necessary. The comment directed at sample size was addressed earlier. An analysis of the historical data and the current data did not discover any bias associated with the sample design.

FISH/SHELLFISH STUDY NO. 3

Comment: Sampling three oiled streams and two non-oiled streams is inadequate for the pink salmon portion of the study since interstream variability will be high.

Response: This study underwent extensive review in the winter of 1989-90. The experimental design is considered appropriate for this study.

Comment: The pink salmon portion of the study should be repeated for two years (1990 and 1991) so that both even-year and odd-year runs are sampled.

Response: The project is intended to last for at least four years so two years in both cycles will be covered. This is contingent on funding.

Comment: The study of streams for pink salmon and watersheds for sockeye salmon is questionable.

Response: A large component of the pink salmon population in PWS spawns in the intertidal area of small streams. The intertidal areas of many streams were oiled. The pink salmon streams being studied are systems where most spawning occurs in the intertidal area. In addition, the near shore areas of PWS serve as the primary nursery areas for pink salmon fry. Destruction of this habitat could negatively impact pink salmon populations. This also holds true for sockeye systems. Although the lake systems which produce sockeye were not directly impacted by oil, the nursery areas may have been.

Comment: Examination of sockeyes during one year will not provide a good estimate for the other three age groups.

Response: Elements of this study were designed to continue at least until 1995. At least one cycle of year classes will be completed by then.

Comment: Smolt studies should be repeated for each age class.

Response: Elements of this study were designed to continue at least until 1995. At least one cycle of year classes will be completed by then.

Comment: Straying should be studied in only in other than outlying areas.

Response: The cost of examining straying in areas other than those adjacent to the study areas is prohibitive.

Comment: The study does not consider the effects of environmental factors such as circulation, water mass anomalies, winter stream temperatures and zooplankton densities as they influence the fisheries.

Response: It is assumed that the impacts of environmental variables will be equal between oiled and non-oiled areas.

Comment: The sample sizes in the study are too low, making it difficult to draw conclusions by comparing a limited number of streams and hatchery facilities, some oiled and some not.

Response: A statistician has been assigned to review this study. The sample sizes are considered to be appropriate for this study.

Comment: The study focuses too much on gross impact; fewer fish should be taken and examined more closely in a controlled environment. The study should look for more subtle differences such as small percentage changes in viability of eggs or fertility of sperm as this is the type of change that will have a profound long-term effect on the viability of the salmon population.

Response: In reviewing this study, modifications including controlled laboratory studies and a focus on sublethal effects were considered. They have been deemed inappropriate in this particular study, however results from other studies may provide useful data. Subtle effects are difficult to measure.

FISH/SHELLFISH STUDY NO. 4

Comment: The presence or absence of young salmon in known early marine rearing locations should be studied to help determine whether young salmon have been forced out of traditional rearing areas in oiled locations.

Response: As a part of this study, records of fry distribution are being made for a large part of the PWS. If differences occur between oiled and non-oiled years, they will be evaluated.

Comment: Alternatives for restoration should not be confined to locations now producing fish; rather, consideration should also be given to the diversification of hatchery production to include early run stocks for release at as-yet undetermined locations.

Response: Increased hatchery production of salmon is being considered as a means of restoration. Broodstock selection (i.e., run timing) and location of release are important parts of any hatchery plan.

Comment: It may be necessary to go outside PWS for representative samples.

Response: Fry were not collected outside of PWS due to the difficulty in obtaining specialized gear and vessels and cost limitations.

Comment: The fifteen individuals from each size category for each site should be tested for hydrocarbons.

Response: Many fry samples from many parts of PWS were collected in 1989 in a way that will permit hydrocarbon analyses at a later time.

Comment: There is no description of a sampling or assessment methodology that will provide an evaluation of impacts to fish food resources, especially planktonic food available to juvenile salmon.

Response: Studies by the University of Alaska and the NMFS, participants in this study have addressed this problem in the 1990 study plan.

Comment: It will be difficult to document fish kills or long-term impacts on the salmon stocks directly attributable to the spill.

Response: While it may be difficult, it is necessary and appropriate that this damage assessment attempt to identify and quantify injury to salmon stocks attributable to the spill.

FISH/SHELLFISH STUDY NO. 5

Comment: There is no evaluation of straying between streams; increased amounts of straying will bias results.

Response: The analysis will involve testing for significant mixing between streams and controlling for the mixing if it exists.

Comment: There is no evaluation of reduced fecundity or viability due to oil exposure.

Response: Growth is being measured as an indicator of sublethal effects. Data on sublethal effects from other studies will be considered in analyzing the results from this study.

Comment: Two oiled weir sites are inadequate; for statistical validity, a minimum of three per condition should be studied.

Response: Two sites per treatment group is considered sufficient for a statistically valid study.

Comment: Survival rates are a function of many factors such as temperature, abundance of food or predators, as well as oil contamination. There must be a means of quantifying the effect of these factors separately in order to determine which effects are attributable to oil. The study assumes that survival rates in the survey and control areas were equal before the spill, which is unlikely since the control areas are on the southern sides of islands exposed to the GOA while the survey areas are all within PWS. Finally, the study description does not explain how large variations in the survival rates for different races will be accounted for.

Response: This study analyses the differences in survival rates of adult fish between the treatment and control areas. Because these are adult fish, the survival rate is essentially constant from year to year and between areas.

Comment: The objective of assessing the exploitation rates in recreational fisheries of dolly varden and cutthroat trout, over-wintering in oiled and non-oiled areas, is inappropriate in that both species over-winter in fresh water lakes, which were not oiled.

Response: While the dolly varden and cutthroats do over-winter in fresh water lakes, most of the feeding and growth occurs in the salt water where the majority of sport fishing effort occurs. The exploitation rates were obtained through F/S study No. 6, which targeted estimated catch rates of the marine sport fishery.

Comment: There is virtually no useful baseline data for comparison of the linkage between oil contamination and char; the linkage between oil contamination and char and cutthroat trout survival is vague.

Response: In instances where little baseline data exists, studies rely on current and future years comparisons.

Comment: The study does not assess impacts of the oil spill on prey of dolly varden and cutthroat trout.

Response: The study is not intended to or designed to assess the impacts of the spill on the prey of dolly varden and cutthroat trout. While this information would be beneficial, measuring growth of the fish will show damage more directly.

Comment: There should be an additional examination of fecundity of fish and survival of eggs through juvenile life stages between exposed and unexposed groups and inspection of fish for anomalies.

Response: Growth is being measured as an indicator of sublethal effects.

Comment: The objective of looking at exploitation rates is unnecessary and, unless accompanied by careful analysis and supported by additional data, may provide misleading results since recreational fisheries are variable and influenced by many factors.

Response: The exploitation data will be analyzed very carefully. They will be checked only for any drop in exploitation rates above and beyond normal variation.

Comment: Chronic effects, such as disease, damage to organs and other sublethal impacts, should be studied, as should impacts on reproduction and analysis of body burdens of hydrocarbons and other spill-related toxins; the confounding effects of mobility of fish must be considered in assessing catch data.

Response: Growth is considered to be the best index of sub-lethal effects.

FISH/SHELLFISH STUDY NO. 7

Comment: This study should include upper CI.

Response: The Trustees would have preferred to examine all areas outside of PWS but were limited in 1989 by time, cost, and personnel. F/S study No. 27 will be initiated in 1990 and will examine possible impacts on sockeye salmon in upper CI.

Comment: Streams and other areas of LCI should also be assessed for damage.

Response: This study examined several of the major pink/chum salmon spawning streams, both uncontaminated and directly contaminated by oil, in the LCI/Kenai Fiords area.

Comment: The gross method of analysis employed, e.g. counting live and dead salmon and egg and pre-emergent fry densities, does not look at sublethal effects such as contaminant body burden, developmental abnormalities and egg and fry survival. These should be studied in a more controlled environment.

Response: Sublethal effects have been considered and the Trustees have incorporated the collection of this type of data into F/S study No. 8a.

FISH/SHELLFISH STUDY NO. 8

Comment: There is no indication whether this study also uses oiled and non-oiled areas for comparison.

Response: This study compares egg to fry survival for both oiled and non-oiled areas.

Comment: This study is completely research-oriented and therefore not a damage assessment study.

Response: A significant proportion of pink/chum salmon spawn intertidally in the LCI/Kenai Fiords area and, to a lesser degree, in the Kodiak area. These areas were affected by oil from the Exxon Valdez. This study is designed to examine potential differences in egg-to-fry survival between streams that have and have not been intertidally oiled. Thus, it is an appropriate damage assessment study.

Comment: Abundance and over-winter mortality for these species in intertidal areas cannot be extrapolated from the fresh water areas proposed for study in this project.

Response: Significant numbers of pink/chum salmon use intertidal areas for spawning in the LCI/Kenai Fiords area. These intertidal areas as well as the upstream portion of the stream, will be examined separately for overwinter survival.

Comment: A closer look at eggs and fry is needed to provide a greater measure of reliability.

Response: The reliability of the test for differences in egg-to-fry survival due to oiling was examined and the number of streams sampled was adjusted in order to obtain the best balance between historic data, logistical concerns, and statistical validity.

Comment: Juvenile fish should be subjected to a more thorough analysis of growth and examining the daily growth rings of otoliths to determine an estimate of daily growth rate, with comparisons drawn between growth of fish in exposed and unexposed groups should be considered.

Response: This project examines the effects of intertidal oiling on egg-to-fry survival, whereas F/S studies 4 and 9 deal with the effects of oiling on early marine growth. Fry samples were collected from each dig zone for analysis of sublethal effects.

FISH/SHELLFISH STUDY NO. 11

Comment: Sampling 160 transects seems excessive; the study description gives insufficient information on the size of the area to be surveyed.

Response: The number of transects needed to achieve the statistical accuracy desired was calculated in 1989 based on the extent of the 1988 spawn. It was not excessive considering the statistical design of the study. The size of the study area is not known exactly until the spawn occurs each year and miles of spawn is mapped; it is only estimated based on the previous year's extent and location of spawn.

Comment: There are no studies on what effect exposure to oil at an early age has on later development, fecundity, etc.

Response: The 1990 study plan includes an egg mortality study and increased fecundity sampling. These studies include analysis of effects of metabolism of oil on fecundity by examining year effects and looking at genetic aberrations in ovary tissue. The egg mortality project will address direct and indirect impacts of oil on egg survival, viability, hatching success, larval abnormalities and various sublethal and chemical laboratory tests that will quantify damage and establish oiling indices.

Comment: The investigators should consult with investigators for marine mammal studies to ensure that related information needs are identified and factored into the study design since herring likely are an important component of the diet of marine mammals.

Response: Marine mammal researchers that are involved in the NRDA process have consulted with the herring principal investigator on the possibility of contamination of the herring food source. They have complete access to the results of any tests that reveal oil content and contamination.

Comment: Kelp growth should be measured, since there have been reports of reduced kelp growth in oiled areas.

Response: Kelp growth is being studied in the coastal habitat studies.

FISH/SHELLFISH STUDY NO. 13

Comment: There is no rationale given for why the three species of clams were specifically selected in Study No. 13.

Response: The original study included Cockles, Littlenecks, and Butter clams because these species were important from a subsistence and personal use standpoint. Cockles were dropped from the study due to their limited abundance in PWS. Littleneck and Butter clams are particularly appropriate for study given their widespread abundance and considerable background information available concerning the species.

Comment: It is not clear from the project description how growth will be documented nor how examination of growth parameters and the abundance of bivalves two to four years old will give information about temporal changes in growth rates and recruitment between oiled and non-oiled beaches.

Response: Growth is documented by recording shell length for each annulus. Beaches will be resampled and the growth of clams since the spill will be recorded as length at each age. Growth curve parameters will be compared for differences in growth rates between oiled and non-oiled areas. Changes in recruitment will also be determined in four years by comparing numbers of clams within the appropriate size ranges.

Comment: Assuming that the condition being measured is a body condition index (volume of soft tissue to total volume of organism) condition should also be measured on a subset of individuals from the clam studies to provide information comparable to that obtained in the other bivalve studies.

Response: No measurements were taken to determine the condition index of clams at each site.

Comment: The study does not indicate whether bivalves will be allowed to void their gut contents prior to analysis for hydrocarbons (since the presence of hydrocarbons in material in the gut can dramatically alter whole body levels analyzed, the same approach should be used in all studies to obtain comparable information).

Response: Clams sampled for hydrocarbon analysis were removed from the substrate and placed in cleaned aluminum foil and frozen as soon as possible. All hydrocarbon samples were handled in the same manner.

Comment: The number of quadrants should be determined by variability.

Response: Clams from the tidal heights sampled can only be taken during a series of low tides. Because of the limited amount of time and resources available, beaches could not be surveyed beforehand to determine the abundance by tidal height. Estimates of variability could not be made prior to sampling.

Comment: How many individuals will be analyzed for hydrocarbons? Individuals should be analyzed, not as a composite, and numerous individuals should be tested per age class.

Response: Hydrocarbon samples are collected by transect (one composite sample per transect plus one environmental replicate for a total of four per site). The first two clams excavated from a quadrant that are between 2-5 cm are used for this sample. Hydrocarbon sample clams are left unwashed and placed immediately in a hydrocarbon free container (aluminum foil). Onsite aging of clams would be difficult due to time constraints and maintaining an uncontaminated sample. Hydrocarbon samples are determined by weight, and it takes several clams to acquire the 15 grams of tissue necessary to form a sample. Thus, hydrocarbon samples are collected by transect. Onsite aging of clams would be difficult due to time constraints and the need to maintain an uncontaminated sample.

Comment: No reason is given for including only little necks in the study of growth in age analysis. [Same comment was also submitted concerning F/S No. 21.]

Response: Littlenecks were found to have the widest and most abundant distribution through PWS. Extensive background information concerning age and growth of Littlenecks is available for many populations in the Pacific Ocean.

Comment: Monitoring of all sites should be done more often than once in the spring and once in the fall, perhaps monthly. [Same comment was submitted concerning F/S No. 21.]

Response: The present sampling plans require a crew of four to complete one sampling site during a minus low tide. Additional sampling would require more personnel and equipment. [Same comment was also submitted concerning F/S No. 21.]

Comment: Growth and age analysis should also include estimates of growth potential on temperature and contrast with real growth.

Response: Detailed temperature information by site and time was not collected from individual sites. Temperatures and salinities were recorded for each site, however detailed temperature information for sites over time was not collected from individual sites. In assessing the effects the oil spill had on growth, growth potential will be assumed to be the growth achieved by clams at a beach prior to the spill. Measurements from shells collected for length at age analysis prior to the spill provide a record of previous growth.

Comment: ANOVA is not appropriate unless it can be demonstrated that the relationships are at least monotypic and not either the typical bell shape or sigmoid that would be expected from these studies. [Same comment was submitted concerning F/S No. 21.]

Response: The appropriateness of an ANOVA test will be determined before it is employed. Non-parametric tests will be applied if justified. Tests for significance will be applied to each species separately.

Comment: The objectives of this study appeared to be inconsistent with the methods and analyses insofar as the objectives suggested that there would be a one-time sample of bivalves at selected beach sites while the methods and analysis section said that one heavily oiled beach will be monitored bi-weekly from May through September. The objectives should be redrafted to indicate that hydrocarbons will be monitored to determine how hydrocarbon contaminant levels change over time, and the monitoring design should be altered if there are sudden changes in the proportion of dead clams or cockles found on the beach being monitored.

Response: The objective of monitoring a heavily oiled beach over time is to determine hydrocarbon contaminant levels over time. The study design will be modified as necessary based upon ongoing monitoring.

Comment: The project description should be expanded to indicate what will be done if significant levels of hydrocarbons are still being found in bivalves or the survival and productivity rate of bivalves have not returned to prespill levels by the end of the study period. The study should be continued until detectable or potentially harmful levels of hydrocarbons no longer are present in bivalves.

Response: The investigators agree that studies should be continued if potentially harmful levels of hydrocarbons exist.

Comment: There should be a better description of how this study relates to M/M study No. 6, indicating how possible effects of bivalve impacts on sea otters will be detected and quantified.

Response: The 1990 study plan was established recognizing the importance of bivalves to otter and bear populations. Only beaches which are known otter or bear habitat are to be studied.

Comment: With respect to establishing the cause of death by necropsy analysis, sufficient baseline data may not be available to provide an adequate understanding of normal tissues to make such a determination.

Response: Necropsy samples were taken at both control and oiled sites.

FISH/SHELLFISH STUDY NO. 15

Comment: It is impossible to determine whether the sample size is appropriate and whether possible egg hydrocarbon content and survival should be assessed.

Response: Sample sizes have been set based on input from ADF&G biometricians using available data on size frequency and the NRDA protocol for hydrocarbon sampling. Hydrocarbon sample sizes were set in order to keep analysis costs down until presence of hydrocarbons is actually documented. Egg clutch hydrocarbon content is being measured and egg survival is being estimated by comparing average egg number just after extrusion to average egg number just before hatching. Egg survival is also being estimated by counting numbers of dead eggs.

Comment: ANOVA was misused in this study.

Response: During development of the detailed study plans all statistical analyses were reviewed by ADF&G biometricians. All statistical analyses being used are considered to be appropriate.

Comment: There is no indication in the study description of whether long-term effects of exposure on young shrimp are being studied.

Response: This study was planned to last for a three to five year period. This would allow time for young of the 1989 year shrimp to grow to the age where they recruit to the gear and could be sampled several times before the study ended. At that time, their relative abundance and level of hydrocarbon contamination could be determined.

Comment: This study should not be part of the damage assessment effort because only very low concentrations of oil have been documented in the water column, and adult shrimp are not particularly sensitive to such low concentrations in the water.

Response: Spot shrimp larvae were in the water column during the oil spill and are known to be very sensitive to oil. By extending this study until these animals recruit to the gear it should be possible to assess their relative abundance compared to previous year classes. Additionally, oil has been documented in bottom fish which inhabit depths similar to spot shrimp. It is therefore possible that oil is on the bottom in spot shrimp habitat, which could be particularly damaging to eggs which are carried externally and have a high oil content.

Comment: Any results generated by this study will be inconclusive in demonstrating an exposure pathway).

Response: Other studies of injury to larval animals, sediments, and other bottom dwelling fish and shellfish will provide supporting information to help identify the probable mechanism for contamination.

FISH/SHELLFISH STUDY NO. 17

Comment: Fish should be examined for parasites, oiled stomach contents and general condition and efforts should be made to determine the age of the fish caught in order to determine what proportion of the population is being counted and to demonstrate whether age-dependent effects are being observed.

Response: Fish will be examined for conditions such as these. Abnormalities in fish will be noted and age will be determined.

Comment: Organoleptic testing should included in other studies.

Response: Organoleptic sampling is being conducted by the Alaska Department of Environmental Conservation (ADEC) outside of the NDRA process.

Comment: Standard hydrocarbon analysis should be done on these fish in addition to organoleptic testing.

Response: Tissue samples for standard hydrocarbon analysis will be collected and analyzed where screening techniques indicate analysis is necessary.

Comment: There should be an estimate of density, growth and age structure of the population.

Response: Age structure will be estimated but, due to the objectives and design of this particular study, growth will not.

Comment: It is unlikely that this study will demonstrate an exposure pathway since only adult rockfish, which normally are in subtidal areas deeper than 20 meters, will be collected.

Response: Because rockfish were found to contain high levels of hydrocarbons, this year's study was expanded to include looking at the prey of rockfish in order to investigate this possible pathway.

Comment: There is insufficient information in the study description regarding the criteria used to select reefs to determine whether they adequately represent the PWS population.

Response: The ten reefs in this study were chosen because there was historical data on them and because they were representative of areas that were heavily oiled and areas not oiled over the geographic area of the Sound.

Comment: The organoleptic testing program needs to describe how the taste panels will be chosen and what criteria will be employed, stating that the study will not yield valid results unless trained taste panels are employed under rigorously controlled test conditions.

Response: Organoleptic testing was done by ADEC following well-established testing procedures.

Comment: The methodology of collecting rockfish by visiting the location of observed fish kills is inappropriate in that it is based on the presumption that the fish were found in the location where they were killed, which is unlikely.

Response: The results of the 1989 field study do not support this comment.

Comment: The use of long line gear for estimating changes in fish abundance is questionable.

Response: Long line gear will not be used for estimating abundance but rather for presence or absence and for the collection for fish of hydrocarbon testing.

Comment: This study appears to be well conceived, but there should be an assessment of the effects on reproduction as a result of hydrocarbon loading and impacts such as fecundity, egg and larval abnormalities and survival should be assessed. There should be research focusing on identifying any possible long-term, chronic effects that decrease survival of exposed fish.

Response: Some of these sub-lethal effects will be addressed in the 1990 field studies.

FISH/SHELLFISH STUDY NO. 18

Comment: There appear to be some discrepancies between the methodologies used in this study and those used in study No. 24. For example, stomach contents will be analyzed in No. 18 but not in No. 24, and bile analysis appears to be undertaken in study No. 24 but not in study No. 18. Bile analysis should be included in study No. 18.

Response: Current study plans for these projects both reference bile sampling and analyses. Study No. 18 is not currently scheduled to take stomach contents but will be reviewed to determine whether stomach sampling and tissue sampling are warranted. Study No. 24 will also be measuring other chemical presences and will record any abnormalities found in the fish sampled. Stomach samples taken under Study No. 24 will be analyzed for hydrocarbon presence if bile samples are found to be positive.

Comment: The study should include growth analysis.

Response: For a fast growing species or life stage of fish, growth rates area valuable indicator of injury. Growth measurements are being used in juvenile salmon damage assessment studies since these fish are growing rapidly. Most adult fish that have long lives grow slowly. For many species, growth rates are too slow to measure impacts over a short time frame.

Comment: It is unlikely that fish will live long if they are ingesting tar balls and the result will be an underestimate of fish populations.

Response: Tar ball ingestion has not been extensively documented in samples of fish taken to date. The sampling of fish in association with the 1990 studies should show some evidence of tarball ingestion if this is significant problem.

Comment: It is extremely difficult, if not impossible, to document an oil spill impact on stock size and year class strength of a commercial fishery species by conventional stock assessment techniques because there is too much natural variability in space and time in these parameters. [Same comment was also submitted concerning F/S No. 24.]

Response: Large fluctuations in the natural survival rates of many marine fish and invertebrate species does make it difficult to determine injury resulting from oil contamination. For this reason. some of the fish stocks being studied are being examined only to determine whether the injury has occurred and not to determine the impact on stock size.

Comment: Measuring the incidence of tar balls in the demersal environments and in stomachs of ground fish is a seriously flawed objective since fish can swallow tar balls that are caught in the trawl. [Same comment was submitted concerning F/S No. 24.]

Response: The Trustees believe that this comment is without merit. Fish are stressed during capture and generally are regurgitating when brought on deck or put in live tanks. Organisms can be observed in the mouth or gill cover that may have been collected during capture, but there is no evidence from stomach contents that fish swallow items during capture.

Comment: The resources addressed by this study are commercial resources and therefore are not proper subjects of the damage assessment. [Same comment was submitted concerning F/S No. 24.]

Response: As noted above in the response to general comments, the resources addressed by these studies are public resources and are therefore appropriate subjects for damage assessment. Many of the fish species sampled are utilized by commercial fishermen, but some are used by subsistence and sport fishermen as well. Some of the species that will be taken by trawls and sampled are currently not extensively utilized in PWS but are an important link in the food chain.

Comment: Given the level of detail presented in this study, it is not possible to determine whether standard and widely accepted sampling, experimental and analytical methods will be used, whether surveys represent assessment areas, whether biases are accounted for and whether results are statistically valid. [Same comment was submitted concerning F/S No. 24.]

Response: The conduct of these projects will be carried out under strict guidelines for sampling and analysis. Survey and sampling plans are designed to be representative as practical considering the large geographical areas and diverse habitats involved. During the planning phases, project plans were provided to highly qualified peer reviewers to ensure that their design was sound in all respects.

FISH/SHELLFISH STUDY NO. 21

Comment: Clams are present in Kachemak Bay and the west side of CI and these areas should be included in the study.

Response: During the 1989 field season sampling was conducted in Jakalof and Seldovia Bays which are both part of the Kachemak Bay system. The major clam species on the west side of CI is razor clams. No razor clams were sampled during 1989, however studies in 1990 include razor clam sampling in CI.

Comment: Why razor clams were being studied in this study rather than little neck clams was not explained. The choice of species should be the same in this study as in study no. 13.

Response: The original study included Cockles, Littlenecks, and Butter clams because these species were important from a subsistence and personal use standpoint. Cockles were dropped from the study due to their limited abundance in PWS. Littleneck and Butter clams are particularly appropriate for study given their widespread abundance and considerable background information available concerning the species.

Comment: The number of quadrants should be determined by variability.

Response: Clams from the tidal heights sampled can only be taken during a series of low tides. Because of the limited amount of time and resources available, beaches could not be surveyed beforehand to determine the abundance by tidal height. Estimates of variability could not be made prior to sampling.

Comment: How many individuals will be analyzed for hydrocarbons? Individuals should be analyzed, not as a composite, and numerous individuals should be tested per age class.

Response: Hydrocarbon samples are collected by transect (one composite sample per transect plus one environmental replicate for a total of four per site). The first two clams excavated from a quadrant that are between 2-5 sm are used for this sample. Hydrocarbon sample clams are left unwashed and placed immediately in a hydrocarbon free container (aluminum foil). Onsite aging of clams would be difficult due to time constraints and maintaining an uncontaminated sample. Hydrocarbon samples are determined by weight, and it takes several clams to acquire the 15 grams of tissue necessary to form a sample. Thus, hydrocarbon samples are collected by transect. Onsite aging of clams would be difficult due to time constraints and the need to maintain an uncontaminated sample.

Comment: The beaches proposed to be studied in this project were impacted by weathered oil, therefore any possible effects to the bivalves would result from this weathered oil.

Response: The study is designed to test for differences between oiled and unoiled sites. The differences will be correlated with hydrocarbon levels whether from relatively fresh oil or from weathered oil.

Comment: With respect to the statement that necropsy analysis will establish cause of death, sufficient baseline data may not be available to provide an adequate understanding of "normal" tissues to make such a statement. Since uptake of oil can occur in dead invertebrate tissues, the presence of oil alone will not be conclusive.

Response: Necropsy samples were taken from live spcimens only. the necropsy analysis of dead clams was proposed as a contingency, however no dead clams were collected for necropsy analysis.

Comment: The study appears well designed but more details are needed to fully evaluate it.

Response: More details are provided in the 1990 plan.

FISH/SHELLFISH STUDY NO. 22

Comment: From the study description provided it is impossible to tell what the investigators plan to do.

Response: The 1990 study plan contains more details regarding sampling and analysis.

Comment: The expense of this project is not warranted since damage to the crab is likely to be minimal: it is unlikely that an exposure pathway can be demonstrated because oil in the subtidal regions is likely to be minimal and spotty outside of PWS and even if oil were present, it would be a highly weathered crude oil which would not be expected to cause injury.

Response: This comment ignores the fact that certain beaches on Kodiak Island and, especially on the Alaska Peninsula mainland, were heavily coated with oil. In some areas, oil was buried in the intertidal sands by heavy wave action. As Dungeness crab are closely associated with intertidal substrates and actually feed in them when they are covered by tide, the potential for them to contact oil coming off of active beaches is considered high.

Comment: Insufficient information is provided to determine whether the study can detect significant differences between effects due to natural phenomena and those resulting from the oil spill.

Response: Samples are being taken from oiled and non-oiled areas to provide control comparisons for the observation of physical characteristics the program will be documenting. The presence of hydrocarbons in the crabs will be determined by standard analytical procedures carried out on samples of sacrificed crabs.

FISH/SHELLFISH STUDY NO. 24

Comment: There appear to be some discrepancies between the methodology used in this study and in study number 18 in CI. For example, stomach contents will be analyzed in No. 18 but not in No. 24, while No. 24 states that it will analyze bile for the presence of PAH metabolites while this does not appear in the description in No. 18.

Response: Study No. 18 was adjusted to include several tissue types in addition to bile. The 1990 study plans for these projects both reference bile sampling and analysis as well as stomach sampling. Current study plans for these projects both reference bile sampling and analyses. Study No. 18 is not currently scheduled to take stomach contents but will be reviewed to determine whether stomach sampling and tissue sampling are warranted. Study No. 24 will also be measuring other chemical presences and will record any abnormalities found in the fish sampled. Stomach samples taken under study No. 4 will be analyzed for hydrocarbon presence if bile samples are found to be positive.

Comment: The methods for "biochemical analysis" should be clarified. There may not be any "standard" biochemical analyses to assess reproductive damage.

Response: This study seeks to determine whether reproductive impairment has occurred. Accepted scientific methodologies will be used. Samples of various tissues will be taken to document hydrocarbon presence and direct observation of reproductive organs and products will be made to determine abnormalities or dysfunctions.

Comment: The expense of this study is excessive and unreasonable since damage to these resources is likely to be minimal and it is unlikely that an exposure pathway can be demonstrated because oil in the subtidal regions outside of PWS will be minimal and spotty and even if oil were present it would be a highly weathered crude oil which would not be expected to cause injury.

Response: The Trustees have determined that the cost of the study was justified due to the likelihood that the resources addressed by the study were exposed to oil and therefore likely to be injured. Exposure to oil was confirmed by the 1989 samples. Based on these samples, the Trustees have been able to narrow the focus of the study in 1990. The study will be extended to determine whether there is continued exposure to oil. The marine resources of the area affected by the EVOS outside of PWS contain large and valuable resources, many of which are important links in the food chain.

MARINE MAMMALS

MARINE MAMMALS STUDIES COMMENTS

Comment: There is no explanation of the choice to study only select marine mammals when other mammals, such as porpoises, have been identified as being potentially affected.

Response: Studies on Steller sea lions, harbor seals, humpback whales and killer whales were conducted in PWS during the 1989 field season. The selection of these four species was based on the fact that they were the only species from PWS for which a historical database exists that could permit a comparison of pre- and post-oil spill abundance and distribution. Past data on the abundance and distribution of harbor porpoise and Dall's porpoise were not available from PWS.

Comment: The description of the Marine Mammals Injury Assessment should note that a large number of North Pacific fur seals migrates through the spill area. It should also indicate the effects of cleanup activities from the spill on their survival and productivity rates.

Response: Fur seals are a pelagic species and their distibution is generally farther offshore than the areas affected by the oil spill. The Trustees believe the species most likely to be affected by EVOS have been selected for study.

Comment: Previous studies of the effects of oil on cetaceans do not justify the cost of the whale studies in the damage assessment.

Response: The Trustees anticipate comparing the results of prior studies to the responses that are observed in this study to determine the degree of injury as a result of EVOS, and have determined that the cost of this approach with respect to this species is justified.

Comment: The M/M studies will unnecessarily stress the animals. Samples should be limited to those taken from dead specimens or individuals taken by natives.

Response: No cetaceans were sacrificed. Samples were collected from dead pinnipeds and cetaceans found stranded on the beaches as well as from pinnipeds used for subsistence. However, non-oiled pinnipeds were also collected due to low sample size, unsuitability of many of subsistence animals, and the need to obtain samples immediately after sacrifice in order to determine the effect of hydrocarbons on animals that were oiled over time.

Comment: The studies do not indicate how data collected will be relevant to restoration; the only feasible method of restoration of marine mammals is shoreline cleanup and natural recovery.

Response: The question of restoration is not answerable at this time since the extent of injuries has not yet been determined. Once the extent of injury has been determined, the restoration working group will be considering a wide range of activities including retoration, replacement or acquistion of the equivalent marine mammal resources.

Comment: The budgets for the M/M studies are inadequate, particularly with respect to the cost of aircraft and boat survey support.

Response: The current version of the plan contains updated budget figures. Since most salaries are absorbed by government agencies and the figures appearing in the budgets comport with the Trustees' experience regarding similar costs in the past, the Trustees believe that the proposed budgets are the best estimate of study costs.

Comment: Only 10 samples per study will be analyzed; this number of samples is inadequate to identify injury in marine mammals.

Response: There is no limit on the number of samples to be analyzed. The ten-sample figure denoted a prioritization for initial analysis.

Comment: Greater emphasis should be placed on sublethal effects and prey species.

Response: The Trustees agree, and the current plan reflects this suggestion. A major focus of Marine Mammal Studies #1 and #2 is to document displacement of whales from areas heavily impactd by the spill. Such displacement could affect feeding patterns and other behavior.

Comment: Inadequate details for sampling, experimental and analytical methods are given in the study descriptions. Results of the studies should be centrally catalogued and made available to research groups and contractors.

Response: See the 1990 plan. The Trustees have proposed that the data gathered from studies they have authorized, as well as those conducted by the PRP's, be made available jointly to the public.

MARINE MAMMALS STUDY NO. 1

Comment: It is doubtful that this study is capable of determining whether observed changes in distribution, behavior or reproduction of whales can be ascribed to the oil spill.

Response: If an overt change occurs in the abundance, distribution or other life history parameters of the whales, the Trustees believe that cause/effect relationships can be determined. If subtle changes take place, it may be more difficult to evaluate cause/effect relationships.

Comment: This study should be coordinated with studies of prey species, or additional studies of prey species should be undertaken, to assess whether the oil spill has caused observed changes in distribution or behavior.

Response: The findings from this study will be coordinated with those of other related studies. The Trustees agree that additional studies on prey species would be valuable, but implementation of such studies would be extremely difficult given the extensive oil spill area and the lack of baseline data and were thereore considered infeasible.

Comment: The effects of noise from cleanup activities should be evaluated.

Response: The studies on humpback and killer whales will document whether the animals have been displaced from their normal feeding areas. The logs of whale sitings will be examined to determine if any displacement is related to the location of observed vessel activity.

Comment: This study should be combined with the herring studies to reduce costs.

Response: The methodologies and logistics needs of these studies are too different to be effectively combined.

Comment: Studies of the effects of contamination of the food chain through methods such as biopsy, analysis for toxicants, and DNA biomarking, should be conducted.

Response: The Trustees agree that studies addressing the sublethal effect and the effect on whale prey species would be beneficial to the current study. Stomach content samples taken in other studies may document contamination of the lower level organisms in the food chain.

Comment: Surveys should be extended for five years in Prince William Sound, Southeast Alaska and the Kodiak Archipelago. Even though this suggestion may be beyond the scope of CERCLA and the Clean Water Act, it is within the areas of interest of the Marine Mammal Protection Act and the Endangered Species Act.

Response: The purpose of the damage assessment is to support claims for natural resource damages arising out of the oil spill. Therefore, studies that do not support such claims are not included in the damage assessment. They may be appropriate, however, for funding outside the damage assessment process. The Trustees agree that this study should continue this year. The study will be evaluated at the end of the field season to determine whether it should be continued next year. Whale studies off Kodiak have been included this year, as suggested by the reviewer.

Comment: The value of line transect surveys and photo-identification methods of population census is questionable.

Response: Photo-identification methods have been used to estimate population size and recruitment. Line transect surveys were not conducted.

MARINE MAMMALS STUDY NO. 2

Comment: It is questionable whether this study is capable of determining whether observed changes in distribution or behavior of whales can be ascribed to the oil spill.

Response: If an overt change occurs in the abundance, distribution or other life history parameters of the whales, it is believed that a determination of cause/effect relationships can be made. If subtle changes take place, it may be more difficult to evaluate cause/effect relationships.

Comment: This study should be coordinated with related habitat and prey studies to assess whether the oil spill has caused observed changes in distribution or behavior.

Response: The findings from this study will be coordinated with those from other related studies.

Comment: Additional observations should be made in the spring and summer of 1990 to determine the effects of cleanup activities.

Response: This study will be continued in 1990. See current plan.

Comment: Studies of sublethal impacts of oil should be conducted on captive animals.

Response: Measuring the effects of oil on captive animals would require that they be injured or sacrificed. This approach would involve suffering of the animals and would be highly unpopular. Some non-injurious approaches using captive animals are currently being considered.

Comment: Additional study of the effects on killer whales of contamination of habitat and food chain through such methods as biopsy or analysis for toxicants is appropriate.

Response: This is being carried out by related studies in the plan. No whales are being sacrificed for biopsies.

Comment: The use of aerial surveys to determine population parameters is questionable.

Response: This study does not rely on aerial surveys. Past population levels of killer whales in PWS have been obtained through photo-identification techniques. Therefore, this study will emply the photo-identification methods so that a comparison can be made against existing data.

Comment: The scope of the study area should be expanded to include Kodiak because of movement of killer whales between Kodiak and Prince William Sound.

Response: Studies were conducted off Kodiak in 1989. Additional work off Kodiak is planned during the 1990 season.

Comment: Objectives C and D of Marine Mammals Study No. 2 are not feasible without long-term studies and sampling studies using biopsy techniques, DNA biomarking, and analysis for environmental toxicants.

Response: Other approaches using photo-identification of pod structure, behavioral observations and examination of stranded animals may also provide this information.

MARINE MAMMAL STUDY NO. 4

Comment: This study should also have an objective of determining whether observed changes in distribution, abundance, behavior, or productivity may have been caused by spill-related changes in the availability of preferred prey species.

Response: If F/S studies that will be providing information on prey find significant impacts, alteration to incorporate more detailed work on prey items will be considered.

Comment: It would be useful to specify the fish and shellfish studies that are expected to provide information on the effects of the spill and related containment and cleanup operations on sea lion prey species.

Response: This would be useful information and will be considered for inclusion in the next revision of the study plan.

Comment: Without several years of study, the effects of the spill on sea lions will not be apparent.

Response: This study will be conducted in 1990 and evaluated during the winter of 1990-91 for possible future continuation.

Comment: It is not valid to use aerial photography of use of sea lion haul-outs and rookeries because they yield point-in-time counts only and the number of sea lions using any particular haul-out may vary greatly hourly.

Response: Counts using aerial photography were discontinued.

Comment: The study description inadequately describes methods and analyses including methods for measuring premature birth rates, methods for estimating pup production, methods for relating pup production to the impact of the spill, and the statistical design of the study such as the number of sites and the methods for assessing the precision and accuracy of the data collected by the photo surveys.

Response: See the study plan for 1990.

Comment: None of the pup mortalities can be attributed to the oil spill without the benefit of direct observation of the death and the immediate necropsy of the carcass.

Response: All mortalities that are observed will be examined and samples taken for hydrocarbon analysis and histopathology.

Comment: The study description does not indicate the size and adequacy of the "before" data existing on sea lions.

Response: See the study plan for 1990.

Comments: How will effects of a pre-spill population decline be separated from the effects of oil contamination? Trustees should be careful of dismissing a reduction in numbers as the continuation of the trend rather than as a result of the spill. It will not be possible to determine the effects of the oil spill on the sea lion population in the northern gulf since little is known about their population dynamics and the continued decline in pupping found as a result of this study cannot be attributed to the spill since sea lions already are in a state of decline.

Response: Estimation of changes in total numbers is not an objective of this study. The decline in pupping that is expected from historical data will be modelled. The 1990 counts will then be tested to determine whether they are significantly lower than predicted by the historical model.

MARINE MAMMAL STUDY NO. 5

Comment: The study should also state an objective of determining whether observed changes in the distribution, abundance, or productivity of harbor seals may have been due to spill-related changes in food availability.

Response: If F/S studies that will be providing information on prey find significant impacts, alteration to incorporate more detailed work on prey items will be considered.

Comment: The study description should specify which studies are expected to provide information on the effects of the oil spill and cleanup operations on harbor seal prey species (28-18).

Response: This would be useful information and will be considered for inclusion in the next revision of the study plan.

Comment: The harbor seal and sea lion studies are essential in light of the declining harbor seal populations in western Prince William Sound. Several years of study are necessary to determine the effects of the spill on these long-lived animals.

Response: This study will be continued in 1990, and the results evaluated during the winter of 1990-91 for possible continuation beyond 1990.

Comment: It is not clear how the researchers will be able to distinguish the effects of the spill from other factors that have been causing the recent sharp decline in the harbor seal population. It will not be possible to attribute to the oil spill any additional decline in the numbers of harbor seals counted in 1989 given the recent decline in the number of seals. With the methods proposed in this study, it will not be possible to evaluate the effects of the spill on harbor seal distribution at haulouts, although there may be changes in distribution at haulouts, it will not be possible to ascribe that change either to the spilled oil or to other factors. The Trustee should be careful of dismissing a reduction in numbers as the continuation of this trend rather than as a result of the spill.

Response: The expected decline will be modelled using historical data, and counts in 1989 and 1990 will be tested to determine if they are significantly lower than predicted by the historical model. The objective of evaluating effects of the spill on distribution of harbor seals has been deleted from the study.

Comment: The study description provides no information on the statistical validity of the shoreline surveys. For example, there is no description of the number of sites, the location of sites sampled, the number of replicates obtained or the sampling design.

Response: See the study plan for 1990.

MARINE MAMMAL STUDIES NOS. 6 & 7

Comment: The study will not address the proportion of sea otter carcasses that were actually recovered after the spill relative to the total mortality, the study may have underestimated the number of otters affected.

Response: In regard to carcass recovery, the agency has added an additional component, looking at drift and recovery of simulated carcasses, to the Year 2 study to gain insight into this question. The boat surveys reported in the first year damage assessment report included analysis of shoreline data only, due to time constraints. Revised analysis including offshore information is now available.

Comment: Cleanup operations, in addition to the spilled oil, could have adverse affects on the otters.

Response: The study participants will have records on cleanup operations for the different beach segments, and will take these into account in interpretation of results. Future boat surveys will look at the recovery of specific shoreline segments. Relationship between severity of beach oiling and cleanup operations with rate of recovery will be addressed at that time.

Comment: Instrumentation and handling of sea otters is inappropriate, represents harassment of the animals, and will not lead to meaningful results.

Response: The capture and surgery does mean that sea otters are subjected to additional stress. However, available data indicate that this stress has no long-term effects on either the survival or the reproduction of the implanted females. For example, of 58 sea otters implanted in eastern Prince William Sound in 1987, annual survival rate was 98%, which is extremely high for wild animals. Sea otters in Prince William Sound now provide a unique opportunity to evaluate acute and chronic effects of oil, both on individuals and on the overall population. The risk to the animals in the present study is not great, and is justifiable in order to assess damage from the oil and determine future contingency plans. Implantation of radio transmitters is necessary as this is the only way to keep track of individual animals over long periods of time (transmitters should function for almost three years). It is difficult, if not impossible, to continuously study individual animals otherwise, as sea otters are known to move and at times can cover relatively large geographical areas. To obtain estimates of survival and reproduction, repeated observations of individuals must be made. Color-coded flipper tags would be a less invasive way of identifying individual animals, but given the large areas involved, tracking individual animals by flipper tags would be extremely difficult. The same information on survival and reproduction could not be obtained by flipper tags alone. To insure the safest handling of the otters, the nets are checked at least hourly during capture (more frequently than is required by the USFWS Permit Office). If animals show obvious signs of stress or are not in optimal condition, they are released immediately.

Animals that are held are placed in covered kennels and kept in a quiet area until surgery. If animals are held for more than a few hours, they are provided with food. Captures are done by an experienced crew, and surgeries are performed only by a veterinarian approved by the USFWS Permit Office. When capturing pups, abandonment by the female is a concern. To avoid this, the female and pup are usually both caught and the female held until they are released together. When only the pup is caught, the capture crew is extremely careful about making sure the female stays in sight, and recordings of pup calls are played back, to keep the female close by. Pups are not captured in male areas, as males can distract the female while the pup is held. Females are palpated for pregnancy prior to surgery, and if a fetus is detected, the female is released without surgery. The surgical and drug protocols are time tested, and surgery is as near to sterile as field conditions allow. Infections or adhesions resulting from surgery have not been noted to be a problem in any of the telemetry studies to date (including the 1987 study).

Comment: There is a discrepancy between numbers of otters to be instrumented under the permit and the numbers listed in the study plan. There is no explanation of the need to handle and instrument so many sea otters.

Response: In the permit, the agency requested a take of 650 otters in order to obtain a total of 275 animals in optimum condition and of the correct sex/age classes for instrumentation. The agency does not plan to instrument more than 275 otters for this study, and in fact the final number implanted in the wild will likely be very close to 200. Many of the animals caught are released immediately (e.g., younger pups are not instrumented but released upon capture). Instrumented animals will not be repeatedly captured, as this is not the intent of the study. Some incidental recapture of previously handled animals may occur. The study calls for 50 otters in each group (females and pups, east and west), which is the minimum sample size required to obtain statistically significant differences in survival and pupping rates, using commonly accepted levels of significance for wildlife studies.

Comment: The monitoring of the instrumented sea otters must be at a high level.

Response: The quality of the study will depend on the frequency of monitoring of the instrumented otters, and the agency will track as frequently as possible. Some limitations will be imposed by the large area in which the otters may move and by severe weather in winter months. The agency plans to coordinate flying efforts between those two studies to increase the efficiency of radio-tracking.

Comment: There is no indication that the other assessment studies on prey species (shellfish, fish, etc.) would be evaluated in light of the sea otter studies.

Response: The results of assessment studies will be reviewed to evaluate how injury to sea otter prey species may affect sea otters.

Comment: These two studies overlap and duplicate earlier work.

Response: The animals in these two studies represent very different groups, given that those in the M/M Study No. 7 have been through oiling, capture, long-term holding and handling. Their clinical histories and capture locations are known. Monitoring these animals after release should provide extremely valuable information regarding the rehabilitation effort, and therefore this study is critical in terms of future management and oil spill contingency planning. However, the sea otters from the rescue centers are not representative of sea otters in the wild, and the NRDA process must examine wild populations living in areas affected by oil as well as the rehabilitated otters. Thus M/M Study No. 6 is also an essential study. Sea otters studied in an earlier (1987) project in PWS were located in the eastern part of the Sound, and were not exposed to oil.

Comment: There is a lack of detail regarding the statistical design.

Response: The statistical design was reviewed, evaluated and modified to assure statistical validity. The 1990 study plans reflect those comments.

Comment: There is no indication whether these studies are applicable to the restoration process.

Response: The data obtained in the sea otter NRDA studies will be combined with information on carcasses recovered in the oil spill zone and data from previous studies on otters in PWS to construct a population model. From this, a prediction of recovery rate of the population to pre-spill levels will be made. Monitoring of the sea otters and the quality of their habitat in PWS will be required to document the natural recovery process. Options for restoration for injuries to sea otters are being developed through the restoration planning process which includes public input and technical workshops. Addition information on level and type of injuries will be instrumental in sea otter restoration planning.

TERRESTRIAL MAMMALS

TERRESTRIAL MAMMALS COMMENTS

Comment: The terrestrial mammals injury assessment program fails to consider that the only feasible restoration of terrestrial mammal resources beyond immediate shoreline cleanup is natural recovery.

Response: Natural recovery is not the only possible approach to restoration. Alternatives could include: harvest management, transplants, artificial propagation, and protection and enhancement of critical habitats. These and other alternative restoration measures will be considered, as appropriate.

Comment: It is unlikely that the population studies of terrestrial mammals can demonstrate any spill-related injury, and that the methodologies described are incapable of establishing any exposure pathway. Therefore, the studies do not appear to be necessary or cost-effective.

Response: The terrestrial mammals chosen for intensive study were those judged by experts as likely to have sustained injury from the spill. Pathways for hydrocarbon exposure will be established by studies of prey contamination and through examination of tissues in dead and collected animals.

Comment: There are inadequate descriptions of the statistical analyses employed in the terrestrial mammal studies, and it is impossible to evaluate whether any results will be statistically significant.

Response: Public review study plans prepared for 1990 provide descriptions of statistical analyses.

Comment: Many mammals may have been affected by the oil spill, for which there are no injury determination studies, and, to fulfill their trust obligations the trustees must determine short- and long-term injury to all terrestrial mammals. The assessment plan should specify how injury to all mammals potentially affected will be determined.

Response: Terrestrial mammal species chosen for study were those judged by experts as most likely to have sustained injury and expected to provide indications of injuries to other related species.

Comment: There is so little money funded for these studies that it is likely that little effect will be detected.

Response: The most important factor influencing the likelihood of detecting an effect is the quality of study design. The studies were carefully considered with appropriate design a paramount consideration.

Comment: The study plan does not discuss studies of sublethal effects or methods of coordination among terrestrial mammals studies and with economics and restoration studies.

Response: Selection of terrestrial mammal species for study was based upon value to humans, likelihood of impact from oil, ability to identify and quantify injury, and ability to extrapolate information to species not selected for study. Sublethal impacts are a major portion of river otter, bear and mink studies. All three studies will look at impacts on reproduction, and the river otter study will also assess habitat use activity patterns and food habits. Coordination is being accomplished through frequent communications among investigators and meetings with economists and restoration planners, facilitated by administrative changes in the damage assessment program.

TERRESTRIAL MAMMAL STUDY NO. 1

Comment: Since no pathway of exposure to the spilled oil has been established, this study is not pertinent to the NRDA process and should not be included.

Response: The potential pathway of exposure is direct contact with oil or ingestion of contaminated food when deer are present in the intertidal zone. The greatest potential for exposure exists in late winter when deer commonly concentrate in this zone.

Comment: The timing and location (i.e., islands) of transect sampling for deer carcasses are not described.

Response: See study plans for 1990.

Comment: The use of only one affected island and one control island will limit the applicability of study results to other areas.

Response: Expansion to additional sites will be considered if evidence of mortality due to oil is found.

Comment: The current design of this study does not indicate whether the deer collected for tissue hydrocarbon analysis were exposed to oil since deer are not usually in the affected habitat (tidal areas) during August. Therefore, the study will be unable to demonstrate a clear cause and effect relationship.

Response: Deer use intertidal areas at all times of year. They will be collected on or near oiled beaches. It is reasonable to assume that abnormal concentrations of hydrocarbons in tissue are an indication of exposure to oil.

Comment: The need to determine the number of dead deer with rumen contents in the lungs is not explained.

Response: Small to moderate amounts of crude oil consumed by deer and other ruminants may cause direct mortality due to disruption of the rumen fermentation process and aspiration of rumen fluid into the lungs.

TERRESTRIAL MAMMAL STUDY NO. 2

Comment: There are too many variables to be able to attribute a decline of black bear populations due to adverse changes in viability resulting from oil contamination. These include differences in habitat, food habits and population dynamics (especially dispersal) among oiled and control areas. The study description provides no statistical basis for inferring changes in the black bear population from a population model and no information on the sensitivity of the model to initial input conditions, nor is there information on the accuracy and precision of the model predictions. The Kenai Peninsula mainland cannot be used as a control area because habitats there are not comparable to habitats in oiled areas of Prince William Sound.

Response: This study was not implemented as described in the 1989 public review draft. For 1990, it will include a literature review only.

TERRESTRIAL MAMMAL STUDY NO. 3

Comment: The sampling procedures used in this study will likely result in more mortalities in these species than have been recorded as spill-related, and river otters and minks should be studied only if there is convincing evidence that they were exposed to oil and were injury.

Response: Spill-related mortality among these species is largely unquantified. However, significant impact is likely because of concentration of oil in intertidal areas where these animals feed. Collections are a necessary step in establishing exposure to oil.

Comment: The study plan does not describe specific sites, only general areas, of sample and control locations and there is no description of whether there is one site per area or several sites per area. Also, it is unclear whether Kenai and the Alaska Peninsula will be treated in the same way as sites closer to the spill.

Response: See study plans for 1990.

Comment: The objectives of determining mortality, documenting declines in populations, and determining changes in distribution and food habits in oiled and unoiled areas are not achievable because of the lack of baseline data.

Response: These objectives will be achieved by comparing oiled with non-oiled study sites. Certainly, availability of baseline data would be desirable. However, it is not considered essential to complete the damage assessment.

TERRESTRIAL MAMMAL STUDY NO. 4

Comment: The study description provides no statistical basis for comparing brown bear mortality, abundance or productivity between oiled and non-oiled areas, given that an inherent problem with monitoring programs such as this is an inability to detect statistically significant differences between natural effects and those resulting from man.

Response: See study plan for 1990.

Comment: The study description is insufficient to determine the validity of the study design. For example, it appears that there is no study of a non-oiled site for brown bear mortality, abundance, or productivity to be used as a control. Also, there is insufficient information on sample design and whether replicate samples will be obtained.

Response: See the study plan for 1990.

Comment: Mortality and productivity of brown bears in the oil-affected area and control area cannot be compared since habitat use and population characteristics of bears in two areas are likely dissimilar.

Response: The oiled and non-oiled study sites were chosen because of habitat and population similarities. Comparison of mortality and productivity to assess damage is therefore appropriate.

TERRESTRIAL MAMMAL STUDY NO. 6

Comment: This study is not cost-effective because 1) there is no justification for a two-year feeding program since there is no environmental scenario which a two-year study would mimic, and 2) minks' delayed implantation may not be representative of typical mammalian reproductive biology.

Response: An extended program is justified because oil is expected to persist for several years in the intertidal areas where mink feed. It therefore may contaminate food chains, be ingested, and potentially impact reproduction. Findings of this study will have direct application to the identification of injury to wild mink, as well as other mammals that have similar reproductive biology (including otter and bears).

Comment: This study cannot be justified unless there is accurate information available on the amount and condition of oil ingested by minks during the spill.

Response: The amount of oil ingested by wild mink will be estimated by determining hydrocarbon levels in tissue and bile and by measuring the contamination of food items.

Comment: Mammals in affected areas have been exposed to oil that has weathered over time; each stage of reproduction, therefore, has not been affected by oil with the same characteristics, and the study description does not discuss differences in comparisons using weathered oil rather than fresh oil.

Response: Weathered oil will be used in this study.

Comment: There is no description of types of statistical analyses or of criteria for determining numbers of replicates overall (or even by type of assay to be completed).

Response: See the study plan for 1990.

BIRD

BIRD STUDIES COMMENTS

Comment: Bird study budgets appear to be insufficient given the number of bird tissue samples to be taken.

Response: Funds for hydrocarbon analysis for all damage assessment studies are allocated to T/S No. 1, Hydrocarbon Analysis. The bird study budgets, therefore, do not include funds to cover analytical costs.

Comment: Prior relevant research is not referred to in the background or objectives sections of the bird studies and should have been taken into account in designing these studies.

Response: Previous research factored significantly into the development of the bird study plans. The 1990 NRDA plan provides additional information and bibliographies to more fully inform the public of some of the prior research that was reviewed and considered in the development of these study plans.

Comment: The counting and collection of eggs, chicks and adults and performance of necropsies on dead specimens during nesting season is undesirable and will be conducted without proper control experiments.

Response: The Trustees recognize that some of the activities conducted during the NRDA process may result in some additional disturbance to wildlife. However, it is essential that this work be carried out to enable the Trustees to assess, as thoroughly as possible, the scope of injury to trust resources. Therefore it is essential that counts and collections of eggs, chicks, and specimens be carried out as described in the study plans. Every effort has been made to reduce further impact on wildlife species.

Comment: The tone of the Plan evinces a prejudice on the part of the authors about the results of the bird studies. Studies should continue for more than one year; dead birds should be examined for causes of death other than oil; pre-existing data should be used to assess reduced hatchability, decreased reproductive success and the delay of onset of breeding and decreased fertility of eggs rather than invasion of nesting sites; non-invasive measurement of control groups in local areas not affected by the spill should be undertaken instead.

Response: The intention of the Trustees was to outline studies needed to assess damages. In response to information needs and recommendations of the principal investigators, reviewers, and the public, seven of the bird studies are continued this year. Dead birds are being examined to determine, when possible, if causes other than oil caused death. Reduced hatchability will be assessed from various studies, including, but not limited to preexisting data. Appropriate control groups have been selected to increase the accuracy of study results.

Comment: Methods for application of the bird study results to assessment of economic damage are poorly elaborated.

Response: The economics study team is in the process of developing a mechanism to apply the results of the bird studies, as well as the other NRDA studies, to assess economic damages. Various alternatives will be developed. It is not possible to elaborate more fully on that process at this time. Selection of an appreciate mechanism will occur after data on injury are available.

Comment: The studies will not address all injuries to all bird species potentially affected by the spill and the injury to be identified is too limited.

Response: The NRDA process is not intended to address all injuries to all species of birds potentially affected by the oil spill. The selection of the studies evolved from recommendations from knowledgeable scientists regarding species that were likely to have been significantly injured as a result of the spill. In addition, an effort was made to include representative species from which data could be extrapolated to a wider population of birds. The added benefit of attempting to identify specifically all injuries to all affected species of birds likely would not be cost-effective. Injury data will be used to estimate the period of time necessary for recovery of the species and will be synthesized into the restoration planning process as well as into the economic valuation process to determine an appropriate use value. Some data collected during the 1989 and 1990 oil spill years may indicate sublethal impacts such as the success of reproductive (clutch size, fledgling success). Consideration was given to conducting additional studies to identify sublethal impacts, however, the Trustees determined that the cost and feasibility of such studies weighed against the incorporation of such studies in the plan and that adequate evidence exists for determining injury. It was determined that refining estimates of active mortality (for example, B/S No. 1) and identifying impacts of colony population would provide more reliable and useful information in determining injury.

Comment: There is insufficient detail concerning the methods of restoring bird populations and habitat.

Response: Before effective restoration strategies can be identified, it is necessary to determine the extent of the injury. Based upon data collected from the 1989 season, the 1990 plan identifies possible restoration projects. Restoration projects require long-term planning and extensive data -- which were not available at the time the 1989 plan was published.

Comment: More information is needed regarding the qualifications of the personnel conducting the studies.

Response: The principle investigators have been selected because they were qualified in both of two categories: 1) They have worked for a number of years in Alaska specifically with the species concerned with their project, and have published and presented their results in professional meetings, journals, and other venues. 2) They worked for either a federal or state wildlife agency and could therefore be put into the field at very short notice (a few weeks). Listing the qualifications of the personnel used in connection with the NRDA studies is irrelevant to the quality review of the studies. The 1990 study plans provide greater detail on the methodologies of the studies, which allow a better evaluation of the individual studies.

BIRD STUDY #1

Comment: Bird Study No. 1 does not explain how the "minimum mortality" will be used to estimate the "overall mortality" of waterbirds.

Response: The minimum mortality is the total body count. The purpose of bird study number 1 is to improve the accuracy of the estimate of total bird mortality by factoring in the ratio of birds recovered to the ratio lost by drift, sinking, scavenging, unsearched shorelines and failure to find. Results of field trials and information from last year's search efforts will be modelled to narrow the range of mortality estimates.

Comment: There is a lack of detail and inadequate presentation of the study proposal in the NRDA Plan. Concerns regarding methods, statistical reliability, confidence limits, sample sizes, and utilization of prior research were repeatedly mentioned.

Response: These concerns have been addressed in the 1990 Plan.

Comment: Objective A cannot be differentiated from objective B.

Response: Objective A refers specifically to total numbers of dead birds reported to all of the receiving stations. This number would have included birds collected by other agencies, State and Federal, and Exxon. Objective B refers to the number of dead birds picked up in standardized Beached Bird Surveys conducted by the FWS.

Comment: This study's use of the terms "mortality", "lost use" and "habitat" is unclear.

Response: Unless referred to as overall mortality, the term mortality is used to define fractions of the total number of birds which may have died as a result of the EVOS. "Lost use" refers to a loss of use of the defined resource by the public. Loss of habitat refers to a loss of the use of the defined habitat by animal species.

Comment: The term "appropriate numbers" of beaches needs to be clarified.

Response: This term refers to selection of a statistically valid sample size.

Comment: Care needs to be exercised in the interpretation of drift experiments because confidence limits in the proportion of birds reaching the beaches will be large and vary seasonally.

Response: The 1989 drift experiment was considered a "pilot" project designed to gain insight into the statistical and logistical requirements of a large-scale drift project. These concerns have been incorporated into a drift study proposal for the 1990 field season.

Comment: It is unclear whether objectives A and B integrate data collected by Exxon boats.

Response: Birds collected by the Exxon fleets were turned in to receiving centers and were included in numbers of dead and dying birds reported by the FWS.

Comment: It is not clear whether there is adequate information on the historical beached bird survey efforts to draw accurate conclusions, as stated in objective D.

Response: This was unknown at the time the plan was written. After examination of the historical beached-bird data, it was shown to be inadequate to meet objective D and this objective was deleted from further consideration.

Comment: A single season of observations immediately after the spill will be inadequate to meet objective E.

Response: The 1990 study plan indicates that a longer study period is being considered.

Comment: Objective E, which is to calculate overall mortality in conjunction with bird population surveys and seabird colony censuses, presents the possibility that the external influences of these other studies will dictate correction factors and any mortality estimates will be nothing more than rough approximations.

Response: Objective E was rewritten to include consideration of numerous other variables in an overall estimate of mortality. It is agreed that present figures quoted as figures of overall mortality are considered preliminary estimates and require further study and analysis.

BIRD STUDY NO. #2

Comment: Bird Studies Nos. 2 and 3 rely on pre- and post-spill surveys for which adequate control sites may be difficult to establish. Instead, to determine cause and effect, these studies should incorporate chromatographic verification of petroleum contamination, gross pathology, histopathology and enzyme assays.

Response: Bird Studies Nos. 2 and 3 are not relying exclusively on pre- and post- spill surveys, but are also assessing results from other studies outside the spill zone that will serve as additional controls. Dead birds archived in frozen storage will be examined to provide additional information on petroleum contamination. Samples taken from fresh bird carcasses last year and from fresh bird carcasses that may be found this year will receive thorough necropsy examination and toxicological and histopathological analyses.

Comment: Blood smears should be taken from apparently healthy birds in B/S Nos. 2 and 3 to examine whether red blood cells exhibit lesions characteristic of hemolytic anemia induced by oil ingestion; collection of liver samples from sick and dying birds and liquid nitrogen assays to ascertain aryl hydrocarbon hydrogenase activity and other mixed-function oxygenase enzymes.

Response: Collection of hematological and liver samples were not part of the objectives of B/S Nos. 2 and 3 which surveyed birds along aerial and boat transects and censused seabird colonies, respectively. Blood samples taken from birds in the recovery centers have been analyzed. In addition, blood samples taken from bald eagles are being analyzed. Liver samples collected from shorebirds and from birds in the recovery center are in frozen storage.

Comment: There is not enough information available on the survey methods to be used in this study.

Response: The aerial survey portion of this combined air/boat Migratory Bird Population Distribution and Abundance Study was designed to determine whether differences in migratory bird population distribution and abundance could be found between historical (1971 survey by Haddock) and the 1989 oil spill year. Aerial surveys began immediately after the spill (within four days) and continued just ahead of the spreading oil. These data, along with later surveys during July and October, were compared in order to determine whether the oil spill caused a major decline in any of the migratory bird species or caused disruption of the normal use of oiled shorelines and nearshore waters by migratory birds.

This survey was designed as an index to migratory bird populations and was not designed to provide a total population of the study area. The entire coastline in the study area was surveyed during March, May, and July. More than 80% of the shoreline was covered during the October survey which was cut short because of inclement weather. Two partial surveys of the shorelines being affected by the spreading oil were completed on April 8, 1989 and again on April 20, 1989.

This survey was intended only as a population index which covered the entire shoreline of the study area. It was not a survey of selected sample areas that would then be extrapolated to the total population of the survey area; therefore, statistical testing was not required. There were no "new" aerial survey techniques used during these surveys. All surveys employed time-proven, standardized aerial survey techniques used throughout the FWS for surveying migratory bird populations.

Haddock's survey of 1971 is the only baseline data available. That survey was done using the same methodology as the 1989 surveys, making the data reasonably comparable. Survey dates for the 1989 surveys were selected to coincide with the approximate dates of the 1971 surveys conducted by Haddock. Oceanographic factors were not integrated into the study design as the survey was designed to closely follow the timing and methods used during that historical survey of 1971.

<u>Comment</u>: Whether recovery rates will be observed accurately is questionable.

<u>Response</u>: Recovery rates cannot be accurately determined following the first year of the study (Objective C). These surveys may be continued for a number of years following the spill in order to identify any residual large scale effects to migratory bird populations and distribution caused by the oil spill. The aerial portion of the combined air/boat study plan did not consider the possibility that age of first breeding would be affected if a large proportion of adults died in 1989.

<u>Comment</u>: The methods of the study were "too briefly presented."

<u>Response</u>: More detail regarding methods is provided in the 1990 plan. Four surveys per year were conducted based on normal seasonal migration of waterfowl and waterbirds. The summer survey was conducted during late July and early August; the fall survey during early October; winter survey during late February and spring survey during May.

Weather parameters for each survey were restricted to a minimum 1,500 ft ceilings, 10 miles horizontal visibility and surface winds of 15 kts or less.

A total of four aircraft, three single-engine, fixed wing and one multi-engine amphibious aircraft were used for the survey in order to complete the survey within a reasonable time period when fair weather could be expected. The fixed wing aircraft contained one pilot and one observer in a side-by-side seating arrangement. The multi-engine amphibious aircraft contained at least one pilot and two observers, one observer seated in the right seat beside the pilot and one seated on the pilot's side of the aircraft.

Single-engine aircraft were used for the shoreline surveys and near shore pelagic surveys. The multi-engine amphibious aircraft were used for pelagic surveys and a few shoreline surveys on distant islands where extended over-water flights were necessary to reach the survey area.

All single-engine, fixed-wing aircraft were configured for float operations. The aircraft were flown at approximately 150 ft above water level and 200 meters off shore, following the shoreline as closely as possible given the aircraft's capabilities, and maintaining an airspeed of 95 - 100 mph. The pilot recorded all birds and sea mammals observed within a 200 meter space out the left side of the aircraft. The observer was responsible for recording all observations within that 200 meter distance between the aircraft and the shoreline, including the immediate shoreline. Date, beginning and ending time of the survey, environmental variables, i.e. wind speed and direction, air temperature, cloud cover and type, ceilings and visibility were recorded for each survey date. Times were recorded on (or about on the hour) throughout each day's survey.

Comment: The planning horizon for these studies should be on the order of a decade rather than a year, and there was a lack of synthesis among studies.

Response: These concerns will be corrected in the 1990 plan by providing more detail. A mechanism is in place to share data among studies and to evaluate how the various studies might aid each other and avoid duplication.

Comment: The objective "Identify potential alternative methods and strategies for restoration of lost use, populations, or habitat where injury is identified" appeared in all proposals without further reference.

Response: This objective has been amended in the 1990 proposal for B/S No. 2. Restoration methods will be addressed after additional data is available to evaluate injury to bird species.

Comment: The budgets were unreasonable.

Response: Apparently, reviewers expected "travel" to include travel within the PWS, whereas, at least in B/S No. 2, it refers only to travel to and from the field. Travel costs within the Sound are contained in other categories, including contracts, supplies and equipment.

Comment: The study should integrate the impacts of oceanographic factors that may have affected seabird distribution and abundance in 1989?

Response: Trustees cannot control such factors, but have attempted to limit their effects on population estimates with an adequate sample size, and by conducting the surveys three times during the summer in PWS. Such repeated sampling was not logistically possible on the KP or in Kodiak Island waters.

Comment: There is no identification of the baseline data to be used in Objective B.

Response: There are data from surveys in PWS in 1972, 1984 and 1985. There have been annual surveys in Kodiak Island waters for 10 years. These surveys do serve as an index to which post-spill data can be compared.

Comment: It will not be possible to determine recovery rates after one season, (and indeed, this may take years). The study design should take into account the possibility that age of first breeding will be affected if a large proportion of adults died in 1989?

Response: The best study design to account for all long-term effects is to conduct the surveys over several years.

Comment: This study and other similar studies appear to be research- oriented and unnecessary to assess natural resource damages as required by NRDA regulations?

Response: Trustees have determined that estimating populations of animals after the spill, and comparing these estimates to previous estimates, is necessary to assess damages and is not research oriented.

Comment: Insufficient information has been provided to evaluate whether this study can determine that any reduction observed in oiled areas represents actual mortality or simply movement out of the area.

Response: This study does not attempt to differentiate between mortality and movement out of the area. In any event, either eventuality might be a result of the spill, and thus considered injury.

Comment: The statistical treatment of the data provided in this study is inadequate.

Response: The 1990 study plan was written so as to avoid this criticism. The sampling design (random selection of transect locations), sample size (i.e. number of transects) and analytical methods were determined using accepted statistical methods.

Comment: Due to the heterogeneity of the natural environment, it is difficult to make valid comparisons between oiled and non-oiled areas with a given year.

Response: One way to mitigate this problem is to use historical data. One can then ask whether a decline from pre-spill to post-spill years in the oiled area is also found in the non-oiled area.

BIRD STUDY NO. 3

Comment: There is need for multi-year work and there are problems associated with the brevity of a two-page proposal or plan.

Response: The 1990 Plan provides for a possible multi-year approach and a more detailed proposal of the study. This allows for a greater understanding of the actions to be taken and greater detail on the experimental and analytical methodology, a geographic scope, and statistical validity of this study.

Comment: Part A of objectives could not be performed without at least a 1990 census.

Response: If the change in population is large enough, a one year series of census may be informative and provide appropriate baseline data. Additional censuses are provided for in the 1990 plan.

Comment: The planning horizon should be a decade, not a year. This was not a "fascination for long-term research," but rather a recognition that the population effects must be dealt with on a time scale consistent with the generation time of the organism under consideration--hence the need for multi-year study projects.

Response: This is correct. As indicated in the 1990 plan, most, and maybe all, questions may need more than one year to find answers.

Comment: There is a lack of specific details concerning census methodology.

Response: The more detailed study plans for 1990 have additional information concerning census methods and data analysis.

Comment: Other control sites, such as Middleton Island, should be used rather than "non-oiled" colonies in PWS, as these colonies could also be suffering various, less obvious effects from the spill.

Response: Although not mentioned in the original study plan, the agency did include data from 1989 work on Middleton Island murres in the February 1990 report. The results there paralleled those observed on the other control, the Semidi Islands. The Semidi Islands were chosen as a control site because they are located farther from the oil than the colonies in PWS, but not so distant as to be unrelated to the same food and biological factors controlling reproduction. Additionally, baseline data from the Semidi Islands is available for certain seabird species in the GOA.

Comment: The possibility exists that birds from non-oiled colonies are being exposed to and affected by oil on their staging or winter habitats, thus confusing comparisons between non-oiled and oiled colony sites.

Response: Ordinarily, this would be a valid concern for seabirds. However, the EVOS was kept relatively close to the shore by wind and current and impacted the winter and staging/migration ranges of seaducks, loons, and those diving seabird species that were present at colony sites (primarily murres). This is one of the reasons that the murres on Gull Island were not used as a control, because the flocks of murres in the vicinity of the Barren Islands may have contained some from other nearby colonies not directly in the spill's path. Murres tend to gather close to colony sites on the water in April and hence the Semedi Islands murres were probably the least likely of our control study sites to be compromised in this fashion.

Comment: The choice of study species is incorrect. Some burrowing alcid, such as Tufted Puffin, should have also been included.

Response: Some burrowing alcid (Pigeon Guillemot) and burrowing procellarid (Fork-tailed Storm-Petrel) species were examined along with the cliff nesting species. Bird Study No. 7 examined storm-petrels and evaluated changes in burrow occupancy. While the colony study (#3) did census pigeon guillemots in some areas, B/S No. 9 covers this species best at the one site where an excellent baseline exists. Over the whole range of the colonies affected by the spill, the examination of the species composition of the 30,000 dead birds recovered before August 1 showed that puffins constituted 0.9 per cent of the total while murres composed 73.7 per cent. There was a surge of immature puffins that died and were collected between August 1 and October 13, 1989. Since all species could not be evaluated, the Trustees chose species demonstrating the most likely effects (morgue) and those with the best baseline of data available (cliff nesters).

Comment: Murres are being excluded from the planned studies except for general abundance and distribution surveys.

Response: Murres do not have an intensive productivity study strictly oriented towards them because no murre colony in the oil affected area is conducive to the type of land-base observations that this requires. However, the sites where this was possible, such as the Semedi Islands and, to a lesser degree at Puale Bay and Middleton Island, have had productivity studies done in 1989 (two by this study and one by another independent FWS group).

Comment: This study is more research oriented and not necessary to assess natural resource damages.

Response: The Trustees do not consider censuses/monitoring of cliff-nesting seabirds such as kittiwakes and murres as research. The term "research" implies that there is no general consensus of the proper techniques to census statistically these species. This comment 15 years ago would have been valid, but it is not now and this is recognized in the literature, professional societies (Pacific Seabird Group), universities, and government agencies.

Comment: This study focuses on cliff-nesters and ignores crevice- or burrow-nesters; there is an unstated assumption that cliff-nesters and burrow-nesters are affected equally by the spill.

Response: The study focused primarily on cliff-nesting seabirds for precisely the reasons discussed earlier: the methods are established, and it is not a research matter. As for the assumption mentioned, no such assumption is stated or implied in B/S No. 3. The important factor is not whether they are cliff- or burrow-nesters; rather it seems like diving birds and their presence or absence at crucial times is the key factor. So diving, burrowing, resident species like Pigeon Guillemot may have been affected negatively while a diving, burrowing puffin which had not returned to the colony until May would not. The same dichotomy could apply to cliff-nesting seabirds in terms of diving versus surface-feeding species. The species composition of the birds picked up from the beaches strongly suggest this. Any assumption underlying these studies is more likely to be based on these considerations.

Comment: Are one or two surveys conducted sometime during the previous 17 years adequate to calculate possible reductions in breeding colony sizes that can be related to oil spill effects.

Response: At least three of the study areas have been censused 6-12 years of the previous 17 years and may provide adequate information to evaluate change.

BIRD STUDY NO. 4

Comment: The study was flawed due to lack of pre-spill data.

Response: While Pre-spill data would have been helpful, it was limited. Comparable population surveys were conducted in 1979 and 1982. These benchmark surveys will provide a point of comparison.

Comment: What is the availability of data collected by Exxon?

Response: The data collected by Exxon in this study is available, but no data collected by Exxon will be used as primary data.

Comment: Is the number of surveys adequate?

Response: To clarify any misunderstanding concerning surveys, both weekly and monthly surveys were and will be conducted in 1990. The weekly surveys will be conducted over a smaller sample area while the monthly surveys will be conducted throughout the spill area. Clarifying language was added to the 1990 proposal.

Comment: There should be additional sites.

Response: The number of sites with comparable data are limited. Locations outside of Alaska will not be used due to the difficulty in demonstrating comparable habitat and ecological condition. The available data from Southeast Alaska and other coastal eagle populations will be used for comparison.

Comment: Details of some methods were not adequately supplied.

Response: More information is supplied in the 1990 plan.

Comment: Methods identified in the study may cause changes in behavior.

Response: Identical methods are used in experimental (oiled area) and control (non-oiled area) populations. Methodologies are standard field practice and unlikely to cause the differences observed between oiled and non-oiled areas.

Comment: Contaminants should be identified.

Response: The contaminants are hydrocarbons found in crude oil, heavy metals indicative of Prudhoe Bay Crude Oil (particularly vanadium and nickel), and other contaminants often found in birds of prey that may be responsible for the observed effects, but not from the spill (DDE, PCB's, and others).

BIRD STUDY NO. 5

Comment: This is a well planned study but preliminary data suggest that few peregrines were present in PWS in 1989 which may prevent completion of parts of this study.

Response: An adequate number of peregrines were present in 1989 to allow collection of data on most parts of this study.

Comment: A survey will have to be done in 1990 to determine whether more than two peregrines still exist in PWS.

Response: Surveys are planned for 1990.

Comment: Chlorinated hydrocarbons should be examined closely with the overall objective of determining which contaminants are responsible if reproductive failures do occur.

Response: Eggs will be collected and analyzed for presence of organochlorine pesticides to assess their possible role in any reproductive failure. See the 1990 study plan for details.

Comment: A small sample of fat should be taken from adults of the species since blood reflects only the contaminants consumed within the last few days, whereas fat reflects the contaminants that have been stored over months or years.

Response: Collection of fat samples was rejected because it is too intrusive and because no baseline data are available in the literature for comparison.

Comment: The information from this study is only marginally important to either damage assessment or recovery and since few of the raptors recovered after the spill were falcons and a substantial raptor study also exists. This study is not necessary or reasonable.

Response: The low recovery rate of falcons may have occurred because the birds died in locations other than on beaches where they likely would be discovered. Studies on other raptors will not provide direct information about impacts on this species.

Comment: It is impossible to determine from the study description if (a) standard and widely accepted methods are employed, (b) possible biases are accounted for, (c) surveys accurately represent assessment areas, (d) possible errors in scaling results are accounted for, and (e) results are statistically valid.

Response: See the study plan for 1990.

Comment: This study inappropriately evaluates new "suspected nesting territories" on which no historical data are available; it further uses new methods, such as helicopter surveys, rather than boats as used in previous surveys making any historical comparisons scientifically invalid.

Response: The study will not rely heavily upon historical comparisons within the study area because very little historical data are available. Therefore, evaluating suspected nesting territories will not be a problem. Helicopter surveys will be supplemented by use of boats to improve comparability to surveys outside the study area that were reported in the literature. See the 1990 study plan for more details.

Comment: Peregrines are not particularly easy to locate, therefore surveys need to be performed with particular care to avoid mistaken conclusions based on inadequate field effort.

Response: Surveys will be conducted by experienced, knowledgeable personnel.

Comment: The study description does not state how methodologies such as helicopter observation, trapping of adults in nets, blood sampling, and inspection of nests will be performed on control groups, which may make study results inconclusive.

Response: Results from the study area will be compared with data reported in the literature. In addition, concurrent and historical population surveys conducted in Norton Sound will provide a partial control.

Comment: The study description does not state how blood samples are to be handled, derivatives extracted and tested, and does not examine whether 20 birds will provide a representative sample or that the loss of blood will not act synergistically with other factors to raise mortality among the test group. The goal should be to collect the optimal minimum amount of blood necessary to run the proposed tests and that collection of more than two to three percent of body weight is strongly discouraged, even in healthy adult birds.

Response: Collection of blood has been deleted from the study.

Comment: A 1990 survey will be required to complete this study.

Response: A survey is planned for 1990.

BIRD STUDY NO. 11

Comment: This study is well-designed and potentially could be concluded successfully in 1989 because it concerns wintering birds, however, hydrocarbon analysis will require more time than the February deadline for completion.

Response: The study will be continued in 1990.

Comment: The term "reproductive potential" is not adequately defined and there is no indication in the methods description as to how this will be measured.

Response: Reproductive potential will not be measured by this study. See the 1990 study plan for details.

Comment: It is not clear what is meant by "intrinsic values" nor is it stated in the methodology how this will be measured.

Response: Intrinsic values will not be measured by this study, but will be considered in the economic studies. See the 1990 study plan for details.

Comment: How many birds will be collected and how will they be collected.

Response: See the study plan for 1990.

Comment: This study is research oriented and is not necessary to assess natural resource damage.

Response: This study is focused very specifically on damage assessment. See the 1990 study plan for details.

Comment: It is impossible to determine from the study description whether (a) standard and widely accepted methods are employed, (b) possible biases are accounted for, (c) surveys accurately represent assessment areas, (d) possible errors in scaling results are accounted for, and (e) results are statistically valid.

Response: See the study plan for 1990.

Comment: The study description does not state any methodology which would conclusively identify what the individual or population effects of the oil spill might be; the objective to "develop a data base describing food habits of sea ducks" is irrelevant to assessing oil effects.

Response: See the study plan of 1990.

Comment: There is no description of statistical analysis and without such analysis any results generated are inconclusive.

Response: See the study plan for 1990.

Comment: The February deadline will have to be extended in order to complete contaminant analysis on samples taken this winter.

Response: The study will continue in 1990.

Comment: There is no mention of results being statistically validated.

Response: This study was reviewed for statistical validity. Additional information is supplied in the 1990 plan.

HISTORIC AND ARCHAEOLOGICAL

ARCHAEOLOGY STUDY COMMENTS

Comment: Archaeological sites are not natural resources and therefore are not properly subject to the CERCLA damage assessment process.

Response: A valuation of the committed use of the cultural attributes of natural resources, as well as the natural components of cultural sites, is properly within the CERCLA damage assessment process.

Comment: The impact of oil on radiocarbon dating, soil chemistry, artifact analysis, and biological decomposition of artifacts should be considered.

Response: The study plan calls for excavation and analyses of soil samples and archaeological materials to identify chemical and physical changes caused by oil contamination. An experiment is planned to determine whether materials normally used for radiocarbon dating can be decontaminated in the laboratory once they have been contaminated by oil. The potential impacts of oil on microanalytical chemical studies is not a focus of the current study plan.

Comment: Surface and subsurface archaeological sites should be included in assessing the impact of oil on cultural resources.

Response: The study plan assesses injury to historic and prehistoric surface and subsurface cultural resources.

Comment: The economic value of replacing an affected archaeological site could not be estimated given that it is a nonrenewable, irreplaceable resource.

Response: The study plan speaks of restoration and rehabilitation of the archaeological resource; options for replacement or acquisition of the equivalent destroyed or injured resources, and an estimation of that cost, remains under review.

Comment: The impact of increased vandalism to archaeological sites should be considered. Similarly, baseline data regarding artifact movement or loss should be determined, and action taken to mitigate any injuries resulting from the vandalism.

Response: The study plan recognizes the occurrence of vandalism to cultural resources in the spill affected area in 1989 and the potential for further vandalism in 1990. The plan calls for site visits to gather baseline data on vandalism and to assess post-shoreline treatment vandalism at a sample of the known sites in the spill area. These data will augment information collected in 1989. Site protection is not an element of the current study.

It is more properly the focus of the Archaeological Resource Protection Act.

Comment: Surface artifacts in immediate danger of loss due to relic collection or natural erosion should be collected.

Response: The study plan calls for field surveys to improve the estimate of the total number of sites in the spill affected area. This project will include collection and curation of artifacts that are in immediate danger of loss through any means.

Comment: A hypothetical clean-up site should be constructed to determine the potential effect of various clean-up methods on archaeological sites.

Response: The cost of replicating an archaeological site in the laboratory is prohibitive and there is no assurance that subsurface field conditions could be duplicated accurately.

Comment: Native corporations should participate in the process of site selection and all data should be available to the corporations for review and comment.

Response: Should sites be selected, in addition to those selected for the 1990 study, the Trustees may consider recommendations from interested parties. The Trustees are considering making data public at an appropriate time, subject to applicable state and federal confidentiality requirements pertaining to archaeological sites.

Comment: The archaeological study should analyze whether the oil spill resulted in increased public knowledge of archaeological sites and whether increased long-term vandalism can therefore be predicted.

Response: The study plan recognizes vandalism as an impact and calls for its identification and quantification; it does not specifically address the long-term potential impacts on cultural resources caused by an increased public knowledge of them. Any prediction would be speculative.

Comment: Each cultural site should be studied individually and, in defining a representative sample, the study should recognize the uniqueness of each cultural site.

Response: The study recognizes that each site is a unique entity, but the limitations of time, personnel, and cost preclude examining each and every site in the oil spill impact area for injury.

Comment: Criteria must be developed to determine which archaeological tests will be performed at each site and to regulate entry onto private lands.

Response: The specifications for the special projects called for in the study plan will contain detailed descriptions of the tests and procedures to be used. Study plan activities do not include entry onto private lands.

Comment: The study should include a provision for the return of culturally sensitive materials that have been curated as a result of the studies.

Response: An objective of the study plan is to allow for the development of a program to restore and rehabilitate archaeological resources. The return of culturally sensitive materials curated as a result of the studies is more properly a subject for consideration during the restoration phase.

Comment: Damage resulting from marine erosion may have been aggravated by oil spill activities and should be addressed in the study.

Response: The study plan calls for investigating erosion which may have been caused or initiated by oil contamination or shoreline treatment activities.

Comment: The Alaska State Historic Preservation Office should be identified as the lead agency for coordinating archaeological injury assessment studies.

Response: The USFS as been designated the lead agency for managing the archeology damage assessment study plan. The State Historic Preservation Officer is the chairperson to the Archaeology Steering Committee, which is responsible for developing and implementing all projects undertaken through the revised study plan.

Comment: Injury to archaeological sites from oil spill clean-up activities should be made a part of the injury assessment process.

Response: The study plan recognizes that shoreline treatment activities may have affected archaeological sites and provides for the gathering of information on actual impacts.

Comment: The funds budgeted for the archaeological study are inadequate to survey the entire spill-damaged coastline.

Response: The study plan calls for a sample survey of the affected shoreline, not its total length.

Comment: A separate operating budget to study impacts to archaeological sites is not specified.

Response: The current study plan includes a separate operating budget.

Comment: The impact on archaeological sites should be included as a component of the intrinsic value study, and contingent valuation methods should be employed to survey Alaska Native and scientist/archaeologist populations.

Response: Effects on archaeological resources may be included in the description of the environment affected by the spilled oil when surveys are administered under E/S No. 7. The stratification of the sample among sub-groups of the population, e.g. Alaska Natives, has not yet been determined.

Comment: Greater detail regarding the procedures to be used to value any damages to archaeological resources caused by the spilled oil and clean-up activities is needed.

Response: General information regarding the economic valuation of archaeological studies is provided in the study plan for E/S No. 9. The specific procedures employed may produce damage estimates used in litigation. They therefore constitute confidential information unavailable during the study process.

Comment: Native corporations should be consulted regarding the choice of experts who will conduct the archaeological study.

Response: The activities conducted to identify any injury to historic properties and archaeological resources will be performed by the contractor that responds to a request for proposals and is awarded the contract. The Trustees will consider informing native Trustees of the status of this process.

Comment: The NRDA Plan ignores possible damage to archaeological sites in low-lying coastal areas affected by the spill.

Response: The study plan provides for the assessment of possible damage to historic properties in submerged, intertidal, and shore margin upland zones along the coastal areas affected by the spill.

Comment: The number of archaeological sites affected by the spill should be determined and site sampling undertaken.

Response: The archaeological resource study provides for a determination of representative sites for historic properties and for sampling of these sites.

Comment: The methods and analyses of the economic studies should incorporate alternative analytical models that have already been developed to value archaeological resources.

Response: Alternative analytical methods and valuation methodologies will be considered.

Comment: The economic valuation of archaeological site injuries appears to consider only known sites.

Response: Economic study No. 9 includes an effort to estimate the population of affected sites.

Comment: Economic study No. 9 does not address compliance, quality control, ways to ensure preservation, or methods of evaluation; furthermore, it does not contain specific proposals that would permit a contractor to conduct a professional job.

Response: Economic study No. 9, as described in the NRDA Plan, is not intended to be a request for proposals from contractors. The archaeology study is designed to identify and quantify damage to historic properties and the study activities will be performed in a manner consistent with Department of Interior Standards and Guidelines for Archaeology and Historic Preservation.

Comment: Injury to archaeological resources should be included in the damage assessment plan.

Response: The 1990 plan includes a study of injuries to archaeological resources and an economic study to assess any damages.

TECHNICAL SERVICES

TECHNICAL SERVICES STUDIES COMMENTS

Comment: The list in Appendix A of petroleum hydrocarbon compounds to be considered for identification and quantification in water, tissue and sediment samples should include the known metabolites of crude oil, especially that from the North Slope.

Response: The Trustees believe that Appendix A contains the proper metabolites that can be identified through this process.

Comment: Appendix A of the Draft Plan omited Section 2.3 of the Quality Assurance/Quality Control Plan.

Response: Sample preservation and holding times are now discussed in Appendix A, Section 2.2 of the 1990 NRDA Plan.

TECHNICAL SERVICES STUDY NO. 1

Comment: The introduction to this study should state that chemical analysis is the only conclusive method for determining the presence and source of oil.

Response: The Trustees agree that in order to determine that a sample contains petroleum hydrocarbons, chemical analysis must be done. This notion is implicit in the plan.

Comment: Technical study no. 1 should extend to cultural resources and evaluate the effect of petroleum exposure on radiometric dating techniques.

Response: This is not a focus of T/S 1. However, an experiment to determine whether materials normally used for radiocarbon dating can be decontaminated, once they have been contaminated by oil, is considered in the Historic Properties and Archaeological Resource Study.

Comment: A defined protocol for sampling, preservation and labelling of samples, analytical practices and measures of quality control/assurance, and an analysis of inter-laboratory comparability is needed.

Response: Protocols for sample preservation, sample labelling, and transporting of samples appear in Appendix A. Analytical standards and quality control for chemical analyses are defined in the QA/QC Plan. The capabilities of individual laboratories are thoroughly reviewed and tested prior to selection for analytical chemistry work to ensure that precise and comparable analyses will be conducted.

Comment: This study should include analysis for the presence of dibenzothiophenes.

Response: All samples that are analyzed will be tested for the presence of dibenzothiophenes.

Comment: Fingerprinting of oil, through gas chromatography/mass spectroscopy of aliphatic and aromatic samples (not flame ionization testing), should be considered for litigation purposes.

Response: Fingerprinting of oil utilizing these methods was undertaken in A/W Study No. 1 in 1989. It is to be continued, as necessary, within T/S Study No. 1 in 1990.

Comment: The method of validating changes in analytical methodology provided for in this study does not permit others to review it so as to ensure that valid data will be generated.

Response: Any changes in analytical methodology will be approved through the use of check samples from the National Insitute of Standards and Technology.

Comment: This study is isolated from field studies in that it does not describe how intrasite variability is taken into account.

Response: Intrasite variability was one of the variables considered in formulation of the sampling scheme. In order to become certified, a laboratory must succesfully analyze the check samples and continue to analyze successfully such samples during round-robin analyses. Each data set is reviewed by QA/QC officers from NOAA and the FWS. No data is released or paid for until it has passed this QA/QC review.

Comment: Metabolites should be examined in all fish sampled for routine hydrocarbon analyses.

Response: Analysis of bile hydrocarbon metabolites will be undertaken on all bile samples from fish.

Comment: The standard protocols for necropsy and preservation of tissue samples should be made available to the public.

Response: The 1990 plan include Appendix B, EVOS Damage Assessment Plan Histopathology Guidelines.

Comment: Neither the "Methods and Analyses" section of this study nor the QA/QC documenting Appendix A contains sufficient information on sampling and analytical methodologies to permit the reader to determine whether analytical data of acceptable quality will be generated. Standard Operating Procedures and NIOSH standards should be made available to the public.

Response: Appendix A includes general information on Standard Operating Procedures for collecting and handling samples for hydrocarbon analysis. The study plan for the 1990 studies include more specific information on procedures to be used in the collection of study-specific samples. NIOSH standards will be included in the report as results and are not included in the study plan.

Comment: The list of hydrocarbon compounds in Appendix A that are to be considered for identification and quantification is "insufficient," as a large percentage of the compounds listed is not found in petroleum at detectable levels or constitutes minor components thereof.

Response: The list of hydrocarbon compounds for which analysis will be conducted was developed carefully to include constituents of crude oil and metabolites that may occur in organisms. While some of these compounds may be minor constituents of crude oil, they may accumulate in organisms and therefore be significant.

Comment: There is no standard given in Appendix A for documentation.

Response: Standards for documentation are provided in the individual laboratory QA/QC plans, which are reviewed by the T/S 1 and the respective agency QA/QC representative.

Comment: There are no criteria identified for laboratory disqualification.

Response: Criteria for qualification of laboratories are defined. Disqualification results from failure to meet the qualification standards.

Comment: The budgets allotted to T/S Studies Nos. 1 and 2 are not sufficient to support a thorough, scientifically and legally acceptable assessment of the oil spill impacts.

Response: The Trustees believe that the budgets allotted to plan studies are sufficient to support the needed work.

Comment: Limitations put on researchers as to the number of samples that can be analyzed or the types of analysis that can be done is unacceptable. All field studies should incorporate standardized QA/QC programs.

Response: No limitations have been put on researchers as to the number of samples they may collect. Not all samples collected will necessarily be analyzed. If valid new analyses are identified, those conducting T/S study No. 1 will evaluate their applicability and adopt them, where appropriate.

Comment: Were appropriate sampling methods used prior to development of the QA/QC plan.

Response: The QA/QC Plan establishes procedures and standards with which the chemical analyses of all hydrocarbon samples must conform. The sampling methods utilized by individual projects may vary due to the large number of different sample types and methods that must be used. The validity of individual project sampling plans is established through a planning process that incorporates extensive peer review. Samples that do not meet the guidelines are annotated in the database.

Comment: Results from intercalibration exercises and data on field and analytical blanks should be included in reports resulting from this study.

Response: The Trustees agree and anticipate incorporating such results in reports. See 1990 plan.

Comment: The budget was too low for this study.

Response: The budget for T/S Study No. 1 is based on the annual workload anticipated for the project. The full funding of this project's needs is assured due to the vital support it provides for the NRDA program and the very high priority it has been given.

Comment: The analytical chemistry will not distinguish North Slope crude from natural seeps in the GOA or CI oil spilled from platforms.

Response: Analytical chemistry can differentiate between sources of oil in samples taken from the environment. In addition, control organisms will be analyzed to establish the concentration of petroleum hydrocarbons in areas not exposed to Prudhoe Bay crude oil from the Exxon Valdez.

Comment: The cost of the study, in view of the lack of a list of the number and types of analyses to be conducted, is enormous.

Response: The cost of this study is based on the projected number of samples that will be analyzed. Analyses with high standards for QA/QC are expensive.

Comment: There are no procedures for generating analytical data of acceptable quality, and review of procedures by the Analytical Chemistry Group is inadequate to provide accountability and assurance of satisfactory data.

Response: The procedures for producing analytical data are very demanding. Each laboratory must check samples correctly before samples are released to it and must participate in round-robin analyses. Furthermore, both NOAA and FWS have internal QA/QC programs and the data produced at contract laboratories must pass these checks before it is released to the data base or to the project leaders.

Comment: It cannot be determined from the description of this study plan whether sufficient replicate samples would be taken to account for intrasite variability.

Response: The number of samples taken, by site, to account for variability is determined for each project during study plan development. Projects are provided peer review and biometric support for sample design.

TECHNICAL SERVICES STUDY NO. 2

Comment: There is no description of how preserved tissues will be sampled.

Response: Methods for sampling tissues are described in plans for other studies.

Comment: More effort should be placed on documenting histopathological responses that may lead to long-term effects such as genetic abnormalities.

Response: A range of histopathological analyses is considered within the context of data needs for individual studies. Documentation of changes that may lead to genetic abnormalities will be considered, as appropriate.

Comment: It is questionable whether sufficient control samples will be taken to determine the range and various attributes of normal cells and tissues.

Response: Collection of control samples is regarded as important for determining the characteristics of normal cells and tissues.

Comment: Frozen tissues of oiled birds collected early in the spill should be examined.

Response: Examination of frozen tissues will be considered in the context of information needs for individual studies.

Comment: It is not possible to determine whether standard histological methods will be used.

Response: See the study plans for 1990.

TECHNICAL SERVICES STUDY NO. 3

Comment: The initial maps, as well as a time table for generation of subsequent maps and their distribution, should have been included in this study plan.

Response: Map documents cannot be included in study plans due to litigation confidentiality, cost, and the density of data, which precludes an 8.5" x 11" format. Mapping in progress is dependent upon data supplied by other projects that have widely varying time tables and information needs. Therefore a timetable for generation of these maps is not possible.

Comment: The GIS should be "intelligent," i.e., it should be capable of incorporating dynamic models of future conditions and integrating different types of existing information into new types of information. There was no indication in the study plan that the GIS would be intelligent and would fully utilize state-of-the-art methods.

Response: "Intelligence" comes with the ability to combine the information layers and project scenarios. The planned GIS will do this.

Comment: The initial maps should have been circulated with the public review draft showing oil damage and movement, the locations of some of the field sites chosen for the coastal habitat study and A/W studies, and sites with historical data.

Response: Oil-induced injury is still being investigated. It will be determined as various studies reach their conclusions. The 1990 study plans will include a generalized map of the geographic extent of oiling. To the extent that the location of sites to be examined in the Coastal Habitat and A/W Studies is not confidential, it is contained in the description of the plan for these studies.

Comment: There should be a system for cataloging and making available to other investigators, as well as the public, the final reports by all the various researchers.

Response: This idea was discussed early in the damage assessment process as a "meta-database," a database index to all of the information databases. No decision has been made by the Trustees regarding the implementation of this concept.

Comment: Because of the lack of detail it cannot be determined what the products of this study will be and whether the study will be cost-effective.

Response: The study plan for 1990 discusses additional data layers that have been added. Products of this study will include maps of data from these data layers and others as requested by investigators and the Trustees. The ultimate products depend on the needs of data users and have not yet been specifically determined.

Comment: No information is given on scale of maps, whether the data base will be pertinent, whether the maps can be used to determine levels of hydrocarbons in the sediments or in the water column, and whether the maps will show the area and levels of impact by chosen hydrocarbon levels.

<u>Response</u>: Maps have been produced in varying scales depending on users' needs. The data layers are discussed in the 1989 and 1990 study plans and are considered by the Trustees to be pertinent. The maps will have the capability of showing results of hydrocarbon analyses in a geographically referenced format.

ECONOMICS

ECONOMICS STUDIES COMMENTS

Comment: Economic studies should not go forward until the Trustees have estimated recovery time since damages for lost use values will be limited to the interim recovery period.

Response: Total damages for lost use value are composed of two elements. These are past lost use values and future lost use values. Future lost use values depend upon the length of time that use of a natural resource has been impaired. Therefore, calculation of future lost use value depends upon estimation of the length of time it will take for injured natural resources to recover. Calculation of use value losses that have already occurred does not involve estimation of recovery periods. There is no reason why these past lost use values cannot be studied at this time.

Comment: The appropriateness of discounting and the discount rate to be employed is questionable.

Response: The ability to compare directly costs and benefits which accrue at different points in time is essential to a comprehensive assessment of the damages attributable to the EVOS. Discounting permits the analyst to convert amounts payable or receivable at different dates into similar terms, i.e., equivalent current (or present) value. With respect to the appropriateness of discounting, in general, unless all relevant costs and benefits occur in the same year, it is necessary to discount the estimated impacts in order to place all attributable costs and benefits within a comparable context.

A specific discount rate has not been selected. The NRDA regulations (43 C.F.R. Section 11.35 (d) 5) state that the discount rate to be used in developing estimates of the expected present value of benefits and costs shall be determined in accordance with Office of Management and Budget Circular A-94 (revised). The Trustees recognize the Office of Management and Budget directive to employ a 10 percent real rate. However, the NRDA regulations are optional, and the Trustees recognize that there is considerable controversy and disagreement within the economics profession regarding the "correct" rate.

Comment: There were several comments on the lack of detail in the economics study plans.

Response: The economic study plans were intended to provide general notice of the types of economic studies that are contemplated. The Trustees believe that the descriptions of the studies are adequate for that purpose.

Comment: The discussion of economic valuation methodologies is inadequate and does not explain how the Trustees intend to implement research methodologies aimed at restoration.

Response: Restoration is the subject of a separate section of the damage assessment plan.

Comment: The economic valuation studies do not state the time period during which damages will be measured.

Response: The period of damage measurement depends upon the time required for restoration or recovery of injured resources. This information will depend on the results of the scientific studies being conducted as part of the damage assessment.

Comment: The Plan is not structured so as to avoid double recovery with respect to such issues as reduced land values and interdependent services.

Response: This comment has been noted and the economic studies will be conducted to avoid double counting of natural resource damages.

Comment: The economic studies fail to take into account the effects of response actions.

Response: Where appropriate, the effects of response actions will be taken into account in determining damages for injury to natural resources.

Comment: Economic studies should be expanded to include evaluation of restoration, replacement, or acquisition of equivalent resources rather than lost use values.

Response: The economic studies are designed to evaluate the losses to economic values resulting from the oil spill. Restoration is the subject of a separate section of the Plan. The Trustees do not view recovery of restoration costs and economic losses to be mutually exclusive. Both restoration costs and economic losses can be recovered as part of a natural resource damage claim, and both of these aspects of the claim are being addressed in the Plan.

Comment: These studies do not account for the degradation in quality of life that will be suffered by the affected fishing communities.

Response: The damage assessment is designed to assess claims that may be brought by the federal and state governments as public trustees for injury to natural resources. To the extent "quality of life" is comprised in part of the intrinsic value of material resources affected by the spill, these issues will be considered in the economic studies.

Comment: The travel cost method of valuing losses to the recreational resource must include participation figures from years beyond 1990.

Response: The decision whether to employ the travel cost method has not been made. Should the travel cost methodology be used, the appropriate time period for travel cost models will be addressed in the study.

Comment: Both willingness to pay for an Alaskan recreational experience and willingness to accept compensation for damage done to the recreational resource should be utilized in the contingent valuation studies.

Response: The use of both willingness to pay and willingness to accept will be considered in the contingent valuation study. The Trustees will use the method that provides the most accurate measure of value.

Comment: A single-point estimate of damages should not be the measure of these losses. Rather, the losses should be reported as distributions.

Response: Ordinarily, a claim for damages is expressed as a single monetary figure. The Trustees also may provide an estimate of the range of possible damages, where appropriate.

Comment: The economic uses studies should better define "economic value" to identify how resources with no commercial value will be valued.

Response: The focus of the economics studies is a comprehensive valuation of the market and non-market value of the goods and services provided by natural resources affected by the oil spill. A number of methods exist for determining the value of resources.

Comment: None of the economic uses studies adequately addresses the intrinsic value of the environment.

Response: Several of the economics studies, e.g., Nos. 5, 6, 7, and 9, will consider damages associated with the loss of intrinsic values in calculating damage estimates.

Comment: Restoration, replacement and the acquisition of the equivalent of injured resources should be the basic measure of damages, consistent with Ohio v. U.S. Department of the Interior; use value alone should not determine the extent of damages.

Response: Restoration is the subject of a separate section of the plan. The plan will evaluate both the cost of restoration and loss of use and non-use values.

Comment: With respect to losses to subsistence households, addressed in E/S No. 6, the effects should take into account that subsistence users who turn to processed food are uninformed about dietary balance, or cannot afford the costs of maintaining a proper dietary balance with commercially produced foods and the loss of raw materials is not easily replaced by purchasing a manufactured equivalent. The handicraft industry, which relies on raw materials, cannot be replaced.

Response: The degree to which substitutes for subsistence uses are adequate will be addressed in the study.

Comment: Under the Plan the damages assessment of the loss of archaeological resources will be understated. Their primary value is intrinsic rather than economic. The impacts on these resources should be evaluated in other of the economic use studies such as numbers 7 and 8. The latter should focus on resource-based expenditures that are necessitated by the spill in addition to studies planned or begun before the spill. The former should specifically address these resources and develop contingent valuation methodologies for determining their value.

Response: The Trustees will consider methods of evaluating the intrinsic value of archaeological and cultural resources. The Trustees will also consider claims for increased resource-based expenditures resulting from the oil spill.

Comment: Economic study No. 7 should extend to cultural resources but protect against further vandalism.

Response: Protection of cultural resources from vandalism is an important regulatory task, but is outside the scope of the damage assessment except as a possible restoration measure for these resources.

Comment: The uniqueness of each archeological site should be considered in valuing these resources and each site should be studied individually. Objective standards should be applied in determining what constitutes a representative site. Criteria for archeological tests should be developed. Provision should be made for return of the studied sites.

Response: The Trustees will take the uniqueness of an archaeological site into account in conducting this study.

Comment: The economic use studies do not deal directly with the effects on tourism.

Response: Tourism is considered in the study of the effects of the oil spill on recreation.

Comment: Economic studies relating to fisheries do not specify the significance of fish prices vis-a-vis damages covered by NRDA.

They fail to address restoration. No valid economic or legal relationship exists between degree of competition in input and output markets and damages related to public trusteeship. The study confuses consumer surplus and product price concepts. These studies may overestimate damages if short-term biomass estimates are based on commercial fishermen's catch rate/harvest data since recreational fisherman experience net gains when commercial efforts are reduced.

Response: This study is intended to evaluate the effects of the oil spill on consumers' surplus in the fisheries market. Consumers' surplus is part of the public value of fishery resources, and is an appropriate part of a natural resource damage claim. The Trustees can recover for lost use values in addition to restoration costs. Restoration is the subject of a separate section of the Plan. In order to evaluate effects on consumers' surplus from the oil spill, study of the competitiveness of the market may be required. The Trustees do not believe that they have confused product price with consumers' surplus. Effects on recreational fisheries from reduction in commercial efforts should be reflected in studies of recreational fishing.

Comment: Economic study No. 4 will double-count losses since land values are based on property use and non-use values, reduction of which are being calculated in other studies. Reduced land values only become losses if sales actually take place before restoration is complete and if the natural recovery period extends beyond the period in which new uses will occur. Increased land values in other areas and lease/permit sales to spill-cleanup and research-related activities should be taken not account as offsets. Overall study costs are likely unreasonable since the compensable damages shown by this study will be very low owing to the low "scarcity value" of lands in Alaska.

Response: The NRDA as a whole will be designed to avoid or take into account any double-counting among individual studies. The Trustees disagree with the comment that losses to public land values accrue only on sale of the land. Like any other land owner, the Trustees are entitled to compensation for the decreased value of their land regardless of their immediate intentions for sale or exchange of land. The effect of recovery from injury on land values will be taken into account in the study. Compensating effects will also be considered. Gains to private individuals from, e.g. cleanup work are not an offset to public resources damaged by the oil spill. The Trustees disagree with the conclusion that the value of land comparable to that affected by the oil spill is likely to be low.

Comment: In E/S No. 5, contingent valuation methods are inappropriate because the recreational services are not unique and substitute options are available. Data on changes in recreational participation may be misleading since reductions in some areas may be offset by increases in others and because short-term response to the spill may exaggerate the likely long-term effect.

Response: Where appropriate, substitution effects and long term losses will be considered in conducting this study.

Comment: Economic study No. 6 does not appear to take into account the fact that although some households were negatively impacted by the spill, others were able to supplement their income by participating in spill cleanup efforts. It ignores private litigation by native corporations and Exxon efforts to deliver food and materials to subsistence villages. Losses to subsistence households are not compensable to the Trustees.

Response: The Trustees are not seeking to make private claims, but to evaluate the damage to subsistence uses of resources as a result of the spill. The benefits provided to individual households by PRPs may be a setoff against private claims, but not against claims by public trustees for injury to publicly held natural resources.

Comment: Given the state of the art in contingent valuation survey work, it is improbable that a defensible contingent valuation study can measure intrinsic damages in a situation as complex as this one. The non-use value concepts that are listed in E/S No. 7 are not applicable to a situation like this one, where there is merely a short-term disturbance of the environment and damages may be reversible and subject to restoration.

Response: The Trustees believe that contingent valuation is an appropriate method of measuring losses to intrinsic values in this case. The characterization of the spill as a short term disturbance is unwarranted. While the duration of the effects of the spill may be relevant to determining the extent of losses in intrinsic values, effects need not be permanent to give rise to losses in intrinsic values.

Comment: With the exception of tagging fish, E/S No. 8 does not indicate which research activities were affected by the spill. Nor does it indicate how scientific study delays will be valued. Lost future opportunities do not constitute committed uses and their valuation would be entirely speculative. Furthermore, the spill has created a significant number of research opportunities.

Response: The Trustees are in the process of identifying research activities that were adversely affected by the oil spill. Additional out of pocket expenses caused by the spill will be calculated. Other valuation methods may be considered. Only actual studies are currently being considered. The Trustees disagree with the suggestion that the oil spill created benefits by necessitating study of how much harm it caused.

Comment: Economic study No. 9 does not indicate how damaged archeological study sites will be valued. Suppositions regarding damages owing to upland site erosion or inland contamination appear to be unfounded.

Response: The Trustees have not made a final determination on how damaged archaeological sites will be valued. Damages will be based on actual injury, not supposition.

Comment: The study descriptions do not explain how the assessed damages will be collected/divided.

Response: If the PRPs do not pay the damages voluntarily, damages will be sought through litigation. The Trustees have not established a precise mechanism for determining how damage awards will be allocated among projects to restore, replace or acquire the equivalent of injured resources.

Comment: Researchers should use more than one valuation technique for resources that generate more than one good/service. "Natural resource slander" should be evaluated in analyzing losses that have occurred as a result of changes in human behavior. Valuation should take into account the current and future scarcity, as well as changes in quality, of the affected resources.

Response: Where appropriate, more than one valuation technique may be used for certain resources. The Trustees have not made a final determination regarding whether "Natural resource slander" is an appropriate element of damages in this case. Where appropriate, the Trustees may take into account the scarcity of resources in determining their value.

Comment: Economists and scientists should work together in evaluating the natural resources damages. The studies do not appear to be integrated with the restoration and scientific study plans.

Response: Economists and scientists have worked on the damage assessment plan, and will work together on the assessment.

Comment: A study of the economic damages caused to human health should be done.

Response: Human health is not, in itself, a natural resource. At the same time, use of natural resources may be impaired where they are contaminated to the extent that they pose a threat to human health. Thus, human health implications of the oil spill are addressed indirectly in the assessment by considering health effects of restoration measures, and in determining the loss in value of subsistence resources.

Comment: All of the losses to the commercial fishing industry should be calculated in E/S Nos. 1-3 so as to capture restoration, residual, and lost consumer surplus costs that private litigants may not recover.

Response: This is the objective of these studies.

Comment: Economic study No. 4 should delineate methodologies and have them reviewed by qualified economists.

Response: All economic studies have been reviewed by qualified economists.

Comment: Economic study No. 5 does not identify which of the three methodologies it mentions will be utilized. It should estimate the growth in recreational activities that would have occurred without the oil spill rather than assuming that 1988 figures would have continued.

Response: A final decision has not been made on the precise methodology that will be employed. The Trustees will consider growth in recreation, to the extent that it can be adequately estimated.

Comment: Economic study No. 7 should be designed so as to capture all natural resource injuries, including the loss of pristine character and effects on the ecosystem as a whole in PWS. It should also attempt to calculate the uncertainty of long-term impacts of the spill so as to capture human perceptions of the oil spill's effects appropriately. Willingness to accept and willingness to pay approaches should both be used to calculate losses of intrinsic value. The study should be conducted throughout the United States, perhaps using subgroups such as Alaska residents, subsistence users and the remaining U.S. residents. The spill's impact on archeological sites should be a component of E/S No. 7. Otherwise a contingent valuation study specific to these resources should be undertaken.

Response: The Trustees will consider all these factors in designing the contingent valuation study.

Comment: A restoration plan that includes cost estimates based on restoration/replacement/acquisition values is not the equivalent of a restoration-based damages assessment. Acquisition of replacement habitats should be evaluated since restoration for individual species injured may not be possible.

Response: Restoration is a central focus of the Plan. The Trustees will consider acquisition of equivalent habitats where appropriate.

Comment: The Economic Uses studies have vague and probably unrealistically low budgets.

Response: The Trustees believe that the budgets for the economic studies are appropriate in light of their objectives and the overall needs of the damage assessment.

Comment: The Coastal Habitat study should explain how it will be coordinated with the economic studies and the restoration plan. The mere fact that shorelines were oiled should be considered an injury in the Coastal Habitat studies and assessed economically in E/S Nos. 5 and 7.

Response: Where appropriate, injury to coastal habitats will be taken into account both in restoration and in the determination of economic losses arising out of the oil spill. The precise method of measuring these losses depends on the results of the Coastal Habitat study.

Comment: The contingent valuation studies should take into account both biological and geophysical injuries.

Response: The Trustees will consider biological as well as geological factors in the contingent valuation studies.

Comment: Creating bioeconomic models outside commercial fishing would be useful for the economic studies.

Response: Thus far, commercial fishing is the only area where the Trustees have determined that a bioeconomic model may be useful and appropriate.

Comment: The focus of E/S No. 5 should be expanded to include existence, option and bequest values. Otherwise, the losses will be undervalued. This study fails to identify how a survey respondent is determined to be a recreational user or not.

Response: All aspects of intrinsic value will be considered in the context of the most appropriate economic study for inclusion in the intrinsic value study. Survey respondents could be identified as recreational users by asking them.

Comment: The economic studies attempt to reduce losses to subsistence uses to market values, but they are integral to the native lifestyle and hold non-monetary benefits that are not being valued.

Response: The Trustees will consider measurement of non-market values of subsistence resources.

Comment: In determining economic methodology to be used, the Trustees should have determined whether a restoration/replacement cost or a diminution of use value approach will form the basis of the measurement of damages.

Response: The regulations (43 C.F.R. Section 11.35 (d) 2) state, "If existing data are insufficient to perform the Economic Methodology Determination, this analysis may be postponed until the Assessment Plan review stage at the completion of the Injury Determination phase of the assessment." As stated earlier, use of the regulation are optional. Insufficient data to quickly value the natural resources impacted by the EVOS, due to its size and complexity, made it necessary for the Trustees to postpone the Economic Methodology Determination. Furthermore, the decision in Ohio v. U.S. Department of the Interior indicates that both restoration/replacement and diminution of use and nonuse values are elements of a natural resource damage claim.

Comment: Economic study No. 6 needs quantitative socioeconomic impact studies and ethnographic studies by anthropologists.

Response: Anthropologists will be involved in evaluation of damage to appropriate resources.

Comment: Appropriate E/S No. 1 should take into account other aspects of the 1989 commercial fishery - seafood prices declined worldwide as a result of the oil spill.

Response: Evaluation of market effects of the spill may require an analysis of world markets.

Comment: There is no assurance in the Plan that losses only to committed uses will be measured. It appears from the Plan that E/S Nos. 4, 8, and 9 will quantify losses to resources for which there are only speculative uses.

Response: Because the NRDA regulations are optional, there is no legal requirement that the damage assessment be limited to losses of committed uses in all of the economic studies. Nevertheless, it is the Trustee's current intention to focus on committed uses. E/S Nos. 4, 8, and 9 will quantify losses to potential, not speculative, uses.

Comment: Economics Study No. 4, which extends the trust responsibility to the role of proprietor, is not warranted by the Clean Water Act, CERCLA or the NRDA regulations.

Response: Under applicable law, the federal and state governments are trustees for public lands affected by the oil spill, and are entitled to the loss in value of public lands as a result of the spill.

Comment: Economic study No. 8 should focus on resource-based expenditures that are necessitated by the spill in addition to studies planned or begun before the spill.

Response: Resource-based expenditures necessitated by the spill are not a focus of E/S No. 8. The objective of this study is to determine any injuries and economic loss from research investigations affected by the spill.

RESTORATION

RESTORATION STUDIES COMMENTS

The perceived lack of attention to restoration was a major theme of public comments on the 1989 NRDA plan. Significant changes have been made to the Restoration Planning Project (RPP) in 1990. The scope and budget for restoration planning have been expanded substantially, and it is expected that restoration planning will play an even greater role in the overall NRDA process next year. There is also a commitment to public involvement in the restoration planning process, and a variety of public events have already been held.

Comment: Although restoration was identified as the Trustees' primary objective, the Plan's restoration analysis has been severed from the damage assessment. It should be an integral part of the quantification of injury and determination of damages. The Plan fails to develop a restoration methodology plan or procedures for determining recovery periods or evaluating restoration alternatives or their costs. There should be a resource recoverability analysis showing the amount of time needed by each resource to recover to its baseline state before economic damages are measured.

Response: Although efforts in 1989 focused on the assessment of damages from injury to resources, the RPP is now in fully underway and is part of the NRDA. One of the products of the Restoration Planning Project will be a restoration methodology plan, and in developing that plan the Restoration Planning Work Group (RPWG) is evaluating restoration alternatives and costs. The RPWG is also exploring ways to predict and monitor natural recovery times and is considering how these relate to the selection of restoration alternatives.

Comment: Restoration alternatives should include cleanup and natural recovery as well as acquisition of replacement habitats and equivalent resources. They should include diversification of hatchery production.

Response: Restoration options which address injuries from both the oil itself and subsequent clean up activities are being developed. In determining the appropriate response to these injuries, a wide range of potential restoration projects will be considered, including replacement, acquisition of equivalent resources, diversification of hatchery production, and natural recovery. On-going clean-up activities, per se, are addressed through the response action rather than the restoration program. The Trustees recognize, however, that the long-term presence of oil residues in the environment is an effect of the EVOS that may have to be addressed following the formal clean up-response action.

Comment: Any restoration plan must include discussion of acquisition of equivalent resources for south central Alaska since restoration for the totality of that environment is not possible and because restoration is often very costly given its results. Acquisition opportunities that might be time-limited should be identified. Acquisition of replacement habitats should be evaluated since restoration for individual species injured may not be possible.

Response: Under federal law, sums recovered for injury to natural resources must be used to restore, replace, or acquire the equivalent of injured resources. Consideration of the replacement of habitats and acquisition of equivalent resources will not be restricted to the immediate oil-spill area, and will include southcentral Alaska. Time-limited acquisition opportunities will be identified.

Comment: Restoration must be provided for each species within the class of species an indicator species represents.

Response: In some cases restoration alternatives will be directed toward individual species, including those represented by "indicator species." The primary focus of restoration planning, however, will be on projects that benefit multiple species and ecosystems.

Comment: The objective of restoration should be return to a "without spill" environment rather than a pristine or "pre-spill" environment. "Pre-spill" conditions should not be considered the baseline for purposes of assessing restoration costs owing to the fact that there is natural variance in resource levels, ecological succession and human activities which affect resource levels. The baseline should take into account the uncertainty of being able to establish a baseline.

Response: It is recognized that the environment is dynamic and that some ecological changes would have been occurring even without the EVOS. These factors will be taken into consideration in developing restoration alternatives. However, the Trustees also believe that where information about pre-spill conditions is available, those conditions are highly relevant to the determination of a baseline for restoration work.

Comment: The restoration goal of returning the injured elements of the environment to their pre-spill conditions is unrealistic since pre-spill conditions were not known for seabirds, otters and other pinnipeds, among others.

Response: The restoration goal is not unrealistic and must be evaluated on a resource by resource basis. Targeting indicator species and using an ecosystem approach are two ways of working with the existing baseline data.

Comment: The Plan focuses on lost use values but does not explain how these are consistent with any restoration objective.

Response: The RPWG is working to identify projects to restore the environment as well as the services that the environment provides. Both direct impacts and lost-use and non-use values will be considered.

Comment: The restoration plan should have included preliminary categories of restoration activities and planning so that field and laboratory studies could undertake preliminary evaluations of feasibility and priority.

Response: In 1990, the RPWG has already identified a wide array of restoration alternatives; additional options will be identified on an on-going basis. The feasibility of a limited number of potential restoration projects is being tested in the field in 1990; we anticipate conducting additional feasibility studies in subsequent years.

Comment: The restoration process should recognize the importance of restoration to archaeological sites.

Response: The RPP considers cultural resources, including archaeological sites, to be appropriate subjects for restoration activities. The RPWG is working with concerned organizations and individuals to help identify appropriate techniques for restoration of these resources. Restoration Technical Support Project No. 3 includes development of a feasibility study regarding the stabilization and restoration of archaeological resources.

Comment: The material devoted to restoration planning should contain criteria by which the effectiveness of restoration plans can be analyzed and plans for monitoring/testing success thereof. There is no standard for adequacy of restoration plans.

Response: Criteria for evaluating and plans for monitoring restoration projects are being developed. Preliminarily, criteria against which a project will be considered for inclusion in a restoration plan include: (a) addresses natural resources injured by EVOS, (b) is technically feasible, and (c) is expected to be of net environmental benefit.

Comment: The restoration plan is vague, does not identify who will be responsible for restoration, and appears to plan for restoration only of commercially valuable species. Nor does it appear to be geared toward restoration as soon as possible after the spill. The Trustees should get a restoration plan underway as soon as possible even if it obscures the damage assessment, since the primary objective is to restore the environment.

Response: Although initial efforts focused on the assessment of damages from injury to resources, restoration planning is now fully underway, and is the responsibility of RPWG, a state-federal interagency task force. Restoration plans will become increasingly detailed and substantive as the effort progresses. The RPWG is attempting to bring an ecosystem perspective to the process, and restoration efforts will not be limited to species commercially valuable. The RPWG is identifying restoration needs and opportunities that may be initiated as soon as funds are available. It is not desirable or necessary for restoration planning to obscure or preempt the damage assessment. Rather, the RPP is part of the NRDA. Combined with the results of the other NRDA studies, it should result in the presentation of a damage claim that is sufficient to implement the restoration plan.

Comment: Scant attention is paid in the Plan to restoration. A lead agency should be designated to focus on restoration.

Response: The ADF&G and the U.S. EPA are the lead agencies for the RPP. Restoration planning is now fully underway and will become increasingly important the damage assessment phase is completed.

Comment: The Plan does not indicate that restoration costs will be compared to use values to ensure their reasonableness, as the Ohio v. Department of the Interior case dictates.

Response: Any damage claim presented to the responsible parties will be consistent with applicable law.

Comment: Many of the investigations proposed provide static, rather than dynamic, data needed for assessing predictive changes and for development of a restoration plan. The plan may not be adequate because of the lack of modeling efforts and indications that statistical analysis will be incorporated. Traditionally, restoration planning activities would develop models to predict the fate of oil remaining in the environment and the expected population changes, both natural and oil-related. These models would include natural recovery as a viable restoration alternative.

Response: Natural recovery is being considered as a restoration alternative. The results of research, including modeling exercises, to predict population changes will be considered in development of the restoration plan.

Comment: The Plan will not assess restoration costs. It does not factor in all restoration costs, including non-use values. Specific restoration efforts may be unavailing if the ecosystem has not been restored first.

Response: One of the objectives of the RPP is to identify the costs of implementing potential restoration projects. Specific restoration projects will not be undertaken if the condition of the ecosystem is such that it cannot sustain the resource for which restoration is intended. In general, the RPWG is identifying projects that aim to restore resources at the ecosystem, rather than species, level. Replacement and acquisition of equivalent resources will be considered.

Comment: Damages assessment must take into account restoration/replacement/acquisition costs. This Plan essentially adopts the "lesser of" approach rejected by Ohio v. Department of the Interior. "Lost use value" is an incomplete valuation method. A restoration plan that includes cost estimates based on restoration/replacement/acquisition values is not the equivalent of a restoration-based damages assessment.

Response: The NRDA, which includes the RPP, is taking into account the costs of restoration, including direct restoration, replacement, and acquisition of equivalent resources. The RPP does not follow the "lesser of" approach.

Comment: The restoration plan does not indicate how the coastal habitat and A/W studies will be used in support of the restoration efforts, particularly acquisition of habitat.

Response: As directed by federal law, the RPP seeks to identify restoration options for injured natural resources, including air, water, and coastal habitats. Injury to these resources will be addressed in the restoration plan. Results of the coastal habitat study will be especially helpful in identifying potential sites for restoration projects and by serving as an index to the health of intertidal ecosystems.

Comment: The Plan fails to describe in sufficient detail its scope and design of restoration so as to ensure that restoration of PWS will occur in a scientifically sound, well-organized and cost-efficient manner.

Response: The RPP is fully underway in 1990, and restoration planning will become increasingly detailed and substantive as the process continues.

Comment: The Plan should address methods of ensuring that restoration steps are necessary and avoiding the inaccuracies of relying on extrapolation of long-term damages from short-term impacts.

Response: The restoration methodology plan that will be developed by the RPWG will address methods for determining appropriate restoration steps.

Comment: The Plan states too cursorily the role that natural recovery may play in the restoration process and none of the restoration studies earmark funds for making this determination. Reference should be made in the Plan to the work that has been done in the past on this subject.

Response: Natural recovery is one of the alternatives considered in the restoration plan for each of the injured resources. Restoration Technical Support Project No. 3 includes the development of a feasibility study on "monitoring natural recoveries." Relevant existing information on natural recovery will be considered as part of this process. A literature search for restoration materials in underway.

Comment: Given the lingering effects of spilled oil, funds should be made available for at least ten years to study long-term effects on sea otters as recompense for natural resources, such as dead sea otters, that cannot be restored.

Response: A variety of mechanisms to carry out and support such a program may be appropriate. Replacement and acquisition of equivalent resources are also potential restoration projects that can be responsive to losses of sea otters.

Comment: Restoration objectives in the injury determination studies are inadequate for restoring populations or habitats.

Response: The restoration objectives in the injury determination studies are intended to ensure that field investigators provide appropriate information to the restoration planning group for use in restoration studies. The ultimate objectives of restoration will include restoration of injured populations and habitats.

Comment: There is no delineation of the methods for public input into the restoration planning process.

Response: See current plan.

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