
Draft Fiscal Year 1995 Work Plan Supplement Volume I

Brief Project Descriptions

Prepared by:

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**August
1994**

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Draft Fiscal Year 1995 Work Plan

Supplement Volume I

Prepared for:
Exxon Valdez Oil Spill
Trustee Council

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August 1994

Dear Reviewer:

This document, *Draft Fiscal Year 1995 Work Plan - Supplement Volume I*, contains brief project descriptions of 93 project proposals submitted to the *Exxon Valdez* Oil Spill Trustee Council for funding in Fiscal Year 1995. These 93 projects are those which, after preliminary review, have been assigned to Evaluation Category 1 and Evaluation Category 2.

Projects assigned to Evaluation Category 1 are those that appear to have high restoration benefit and strong technical merit. Projects assigned to Evaluation Category 2 are those that appear to be permissible under the terms of the court-approved civil settlement, but are of a lower priority for funding in FY 95. The preliminary review and categorization were conducted by the Trustee Council's Executive Director, with the assistance of the Chief Scientist, independent peer review scientists, and agency staff. Proposals were reviewed for scientific and technical merit, potential restoration benefit, and legal and policy considerations. The identification of a project in a particular category does not reflect an action or decision on the part of the Trustee Council regarding any specific project or proposal to be funded in FY 95.

Descriptions of projects identified as Evaluation Category 3 (those that lack a clear relationship to restoration or are otherwise of low priority), Category 4 (those with significant legal or policy issues), Category 5 (those that fund only data analysis and report writing efforts associated with 1994 projects), and Category 6 (those that complete projects begun in 1994) are contained in *Draft Fiscal Year 1995 Work Plan - Supplement Volume II*. Budget information for all projects is contained in *Draft Fiscal Year 1995 Work Plan - Supplement Volume III*. Volumes II and III are available for review at the *Exxon Valdez* Restoration Office (see address below), and at libraries and Legislative Information Offices throughout the spill area. Copies of individual project descriptions or budgets may be requested by calling the Restoration Office (see numbers below).

In a number of instances, Category 1 and 2 projects were submitted as multi-project, integrated efforts. These include (1) the Prince William Sound System Investigation, a multi-year research effort to determine what natural and spill-related factors are affecting the health and population of Prince William Sound pink salmon and herring; (2) the Marine Mammal Ecosystem Study, a study of the long-term decline in some marine mammals and seabirds; and (3) the Nearshore Vertebrate Predator Study, which focuses on the status of top-level predators that feed in the nearshore environment. "Overview" documents describing each of these integrated efforts are available from the Restoration Office.

A complete discussion of the Trustee Council's restoration efforts, including the project proposal and evaluation process, is contained in the *Draft Fiscal Year 1995 Work Plan - Summary*. Copies of the summary, as well as additional copies of this *Supplement Volume I* are available from the Restoration Office.

Exxon Valdez Oil Spill Trustee Council Restoration Office
645 G Street
Anchorage, Alaska 99501
Telephone (907) 278-8012 (toll-free within Alaska at 1-800-478-7745;
from outside Alaska at 1-800-283-7745)

Project descriptions contained in the *Draft Fiscal Year 1995 Work Plan - Supplement Volume 1* appear in numerical order. Each project description contains the following information:

Project Number:	A numerical coding assigned for tracking purposes.
Restoration Category:	The means by which a project would achieve restoration goals. The restoration categories are research; monitoring; general restoration; habitat protection and acquisition; administration, public information and science management; and restoration reserve.
Proposed By:	The organization or individual that submitted the project.
Lead Trustee Agency:	For projects not submitted by one of the six Trustee Agencies, the agency that has been assigned administrative responsibility for the project. The six Trustee Agencies are the Alaska Department of Environmental Conservation (ADEC), the Alaska Department of Fish and Game (ADFG), the Alaska Department of Natural Resources (ADNR), the U.S. Department of Interior (DOI), the U.S. Forest Service (USFS), and the National Oceanic and Atmospheric Administration (NOAA).
Cooperating Agencies:	Trustee Agencies, other than the Lead Trustee Agency, that would participate in implementation and management of the project.
Cost FY 95:	The amount of money being requested for the project in federal fiscal year 1995 (October 1, 1994 - September 30, 1995).
Cost FY 96:	The amount of money that will be requested for the project in federal fiscal year 1996 (October 1, 1995 - September 30, 1996).
Total Cost:	The total amount of money, if known, that will be requested to bring the project to completion.
Duration:	The total number of fiscal years, if known, for which money will be requested for the project.
Geographic Area:	The geographic area in which the field work on the project will take place.
Injured Resource/Service:	The resource or service injured by the spill that the project is designed to restore.

The Trustee Council is asking for your comments to help make decisions about the *Draft Fiscal Year 1995 Work Plan*. To use your comments, they must be **postmarked by October 3, 1994**.

DRAFT FISCAL YEAR 1995 WORK PLAN

— Evaluation Category 1 and 2 Projects —
(FY 95 dollar figures in thousands)

Project No.	Project Title	Project Proposer	Project Type	FY 95	Cat.
95001	Condition and Health of Harbor Seals	Castellini, UAF	Research	\$172.8	1
95005	Harlequin Duck Abundance and Productivity in Western Cook Inlet	DOI	Monitoring	\$40.5	2
95007A	Archaeological Site Restoration - Index Site Monitoring	ADNR	Monitoring	\$386.3	1
95007B	Archaeological Site Restoration	USFS	General Restoration	\$116.0	1
95009C	Trophic Dynamics and Energy Flow: Impacts of Herring Spawn and Sea Otter Predation on Nearshore Benthic Community Structure	Highsmith, UAF	Research	\$217.3	2
95009D	Survey and Experimental Enhancement of Octopuses in Intertidal Habitats	Scheel, PWS Science Center	Research	\$188.9	1
95013	Killer Whale Monitoring in PWS	Matkin, North Gulf Oceanic Society	Monitoring	\$113.7	1
95014	Predation by Killer Whales in PWS: Feeding Behavior and Distribution of Predators and Prey	Matkin, North Gulf Oceanic Society	Research	\$177.6	1
95018	Partitioning of Primary Production Between Pelagic and Benthic Communities	Naidu, UAF	Research	\$219.2	2
95019	Distribution and Abundance of Forage Fish as Indicated by Puffin Diet Sampling	DOI	Research	\$271.3	1
95021	Seasonal Movement and Pelagic Habitat Use by Common Murres from the Barren Islands	DOI	Research	\$230.9	2
95023	Food Web Relationships of Pelagic Species Exhibiting Long-term Decline	Duffy, Alaska Natural Heritage Program	Research	\$133.2	2
95024	Enhancement of Wild Pink Salmon Stocks	Reidel, Native Village of Eyak	General Restoration	\$184.0	2
95025A	Factors Affecting Recovery of Sea Ducks and Their Prey	DOI	Research	\$415.1	1

DRAFT FISCAL YEAR 1995 WORK PLAN

— Evaluation Category 1 and 2 Projects —
(FY 95 dollar figures in thousands)

Project No.	Project Title	Project Proposer	Project Type	FY 95	Cat.
95025B	Sea Otter Abundance and Distribution, Food Habits and Population Assessment	DOI	Research	\$168.1	1
95025C	Pigeon Guillemots and River Otters as Bioindicators of Nearshore Ecosystem Health	Roby, UAF	Research	\$189.2	1
95025E	Algal Competition Limiting Recovery in the Intertidal	Stekoll, UAF	Research	\$205.1	2
95025F	Availability and Utilization of <i>Musculus</i> spp. as Food for Sea Ducks and Sea Otters	Dean, Coastal Resources Associates, Inc.	Research	\$5.5	2
95025H	Effects of Predatory Invertebrates on Nearshore Clam Populations in PWS	Van Blaricom, NBS	Research	\$123.4	1
95026	Hydrocarbon Monitoring: Integration of Microbial and Chemical Sediment Data	ADEC, Institute of Arctic Biology, UAF	Monitoring	\$146.9	1
95027	Kodiak Shoreline Assessment: Monitoring Surface and Subsurface Oil	ADEC	Monitoring	\$447.8	2
95029	Population Survey of Bald Eagles in PWS	DOI	Monitoring	\$48.7	2
95030	Productivity Survey of Bald Eagles in PWS	DOI	Monitoring	\$81.9	1
95031	Reproductive Success as a Factor Affecting Recovery of Murrelets in PWS	DOI	Research	\$444.8	1
95033	Kittiwakes as Indicators of Forage Fish Availability	DOI	Research	\$198.5	1
95038	Symposium on Seabird Restoration	Harrison, Pacific Seabird Group	General Restoration	\$74.4	2
95039	Common Murre Productivity Monitoring	DOI	Monitoring	\$154.2	1
95041	Introduced Predator Removal from Islands - Follow-up Surveys	DOI	General Restoration	\$66.5	1
95044	<i>In Situ</i> Formation and Ecotoxicity of Hydrocarbon Degradation Products Produced by Ultramicrobacteria	Button, UAF	Research	\$135.1	1

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— Evaluation Category 1 and 2 Projects —
(FY 95 dollar figures in thousands)

Project No.	Project Title	Project Proposer	Project Type	FY 95	Cat.
95048	Historical Analysis of Sockeye Salmon Growth	Ruggerone, Natural Resources Consultants	Monitoring	\$99.2	1
95051	Large-scale Coded Wire Tagging of PWS Herring	June, Natural Resources Consultants	General Restoration	\$231.9	1
95052	Community Involvement and Use of Traditional Knowledge	ADNR	General Restoration	\$230.5	1
95057	Movement of Larval and Juvenile Fishes within PWS	Norcross, UAF	Research	\$328.1	2
95058	Restoration Assistance to Private Landowners	USFS	Habitat Protection	\$423.7	2
95062	River Otter Recovery Monitoring	ADFG	Monitoring	\$55.9	2
95064	Monitoring, Habitat Use, and Trophic Interactions of Harbor Seals in PWS	ADFG	Research	\$347.1	1
95069	Restoration of Salmon Stocks of Special Importance to Native Cultures	ADFG	General Restoration	\$665.7	2
95074	Herring Reproductive Impairment	NOAA	Research	\$407.2	1
95075	Population Structure of Blue Mussels in Relation to Levels of Oiling and Densities of Vertebrate Predators	NOAA	Research	\$197.5	2
95076	Effects of Oiled Incubation Substrate on Survival and Straying of Wild Pink Salmon	NOAA	Research	\$179.9	1
95086A	Coastal Habitat Intertidal Monitoring and Experimental Design Verification	Stekoll, UAF	Monitoring	\$892.6	1
95086C	Herring Bay Monitoring and Restoration Studies	Highsmith, UAF	Research	\$904.2	1
95087	Relation of Sea Urchin Population Structure to Recovery of Injured Nearshore Vertebrate Predators	Jewett, UAF	Research	\$48.8	1

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— Evaluation Category 1 and 2 Projects —

(FY 95 dollar figures in thousands)

Project No.	Project Title	Project Proposer	Project Type	FY 95	Cat.
95089	Information Management System	Executive Director's Office	Administration and Public Information	\$590.7	1
95090	Mussel Bed Restoration and Monitoring in PWS and Gulf of Alaska	NOAA, ADEC	Monitoring	\$438.8	1
95092	Recovery Monitoring of PWS Killer Whales	NOAA	Monitoring	\$110.0	1
95100	Administration, Science Management and Public Information	Executive Director's Office	Administration and Public Information	\$3,596.9	1
95105	Kenai River Ecosystem Restoration Pilot Enclosure Study	ADFG	General Restoration	\$404.8	1
95106	Subtidal Monitoring: Eelgrass Communities	Jewett, UAF	Monitoring	\$200.4	1
95115	Sound Waste Management Plan	PWS Economic Development Council	General Restoration	\$352.2	1
95117-BAA	Harbor Seals and EVOS: Blubber and Lipids as Indices of Food Limitation	Castellini, UAF	Research	\$94.4	1
95118-BAA	Diet Composition, Reproductive Energetics and Productivity of Seabirds Damaged by the <i>Exxon Valdez</i> Oil Spill	Roby, UAF	Research	\$140.6	1
95120-BAA	Proximate Composition and Energetic Content of Selected Forage Fish Species in PWS	Worthy, Texas A&M University	Research	\$43.0	1
95121	Stable Isotope Ratios and Fatty Acid Signatures of Selected Forage Fish Species in PWS	Worthy, Texas A&M University	Research	\$48.1	2
95126	Habitat Protection and Acquisition Support	ADNR	Habitat Protection	\$1,099.5	1
95131	Clam Restoration (Nanwalek, Port Graham, Tatitlek)	Nanwalek and Port Graham Village Councils	General Restoration	\$445.0	1

DRAFT FISCAL YEAR 1995 WORK PLAN

— Evaluation Category 1 and 2 Projects —
(FY 95 dollar figures in thousands)

Project No.	Project Title	Project Proposer	Project Type	FY 95	Cat.
95132	Port Graham and Nanwalek Subsistence Baseline	Port Graham Village Council, Nanwalek Village Council	General Restoration	\$518.7	2
95133	English Bay River Sockeye Salmon Subsistence Project	Kvasnikoff, Nanwalek Traditional Council	General Restoration	\$147.2	2
95137	Prince William Sound Salmon Stock Identification and Monitoring Studies	ADFG	General Restoration	\$277.5	1
95138	Elders/Youth Conference	Fall, Subsistence Division	General Restoration	\$85.8	1
95139A	Spawning Channel - Port Dick Creek	ADFG	General Restoration	\$33.2	2
95139C	Montague Riparian Rehabilitation	USFS	Habitat Protection	\$46.2	2
95159	Surveys to Determine Additional Oil Spill Effects and Recovery of Marine Bird and Sea Otter Populations in PWS	DOI	Monitoring	\$426.8	2
95163	Abundance and Distribution of Forage Fish and their Influence on Recovery of Injured Species	NOAA	Research	\$1,294.6	1
95166	Herring Natal Habitats	ADFG	Monitoring	\$512.8	1
95173	Factors Affecting Recovery of PWS Pigeon Guillemot Populations	DOI	Research	\$408.8	1
95191A	Investigating and Monitoring Oil Related Egg and Alevin Mortalities	ADFG	Research	\$265.0	1
95191B	Injury to Salmon Eggs and Pre-emergent Fry Incubated in Oiled Gravel (Laboratory Study)	NOAA	Research	\$331.0	1
95244	Seal and Sea Otter Cooperative Subsistence Harvest Assistance	ADFG	General Restoration	\$89.9	1
95255	Kenai River Sockeye Restoration	ADFG	General Restoration	\$645.0	1
95258	Sockeye Salmon Overescapement	ADFG	Monitoring	\$998.1	1

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— Evaluation Category 1 and 2 Projects —
(FY 95 dollar figures in thousands)

Project No.	Project Title	Project Proposer	Project Type	FY 95	Cat.
95266	Shoreline Assessment and Oil Removal	ALL	General Restoration	\$1,411.1	2
95272	Chenega Chinook Release Program	Olsen, PWS Aquaculture Corporation	General Restoration	\$47.2	1
95279	Subsistence Restoration Project	ADFG	General Restoration	\$241.6	2
95290	Hydrocarbon Data Analysis, Interpretation, and Database Maintenance for Restoration and NRDA Environmental Samples Associated with the <i>Exxon Valdez</i> Oil Spill	NOAA	Monitoring	\$163.4	1
95320A	Salmon Growth and Mortality	ADFG	Research	\$267.8	1
95320D	PWS Pink Salmon Genetics	ADFG	General Restoration	\$227.0	2
95320E	Juvenile Salmon and Herring Integration	ADFG	Research	\$943.1	1
95320G	Phytoplankton and Nutrients	McRoy, UAF	Research	\$239.3	1
95320H	Role of Zooplankton in the PWS Ecosystem	Cooney, UAF	Research	\$247.4	1
95320I(1)	Isotope Tracers - Food Web Dependencies in PWS Using Stable Isotopes (Marine Mammals and Birds)	Schell, Institute of Marine Science	Research	\$115.4	1
95320I(2)	Isotope Tracers - Food Webs of Fish	Kline, UAF	Research	\$79.4	1
95320J	Information Systems and Model Development	Patrick, PWS Science Center	Research	\$836.2	1
95320M	Observational Physical Oceanography in PWS and the Gulf of Alaska	Salmon, PWS Science Center	Research	\$577.8	1
95320N	Nearshore Fish	Thomas, PWS Science Center	Research	\$635.2	1
95320Q	Avian Predation on Herring Spawn	USFS	Research	\$99.0	1

DRAFT FISCAL YEAR 1995 WORK PLAN

— Evaluation Category 1 and 2 Projects —
(FY 95 dollar figures in thousands)

Project No.	Project Title	Project Proposer	Project Type	FY 95	Cat.
95320S	Disease Impacts on PWS Herring Populations (competitive solicitation under State of Alaska two-step, RFQ-RFP process)	ADFG	Research	\$379.9	1
95320T	Juvenile Herring Growth and Habitat Partitioning	ADFG	Research	\$340.3	1
95320U	Somatic and Spawning Energetics of Herring and Pollock	Paul, UAF	Research	\$99.4	1
95320Y	Variation in Local Predation Rates on Hatchery-Released Fry	Scheel, PWS Science Center	Research	\$161.2	1
95424	Restoration Reserve	ALL	Restoration Reserve	\$12,000.0	1
95427	Harlequin Duck Recovery Monitoring	ADFG	Monitoring	\$226.9	1
95505B	Data Analysis for Stream Habitat	USFS	Habitat Protection	\$17.2	1

**DRAFT FISCAL YEAR 1995 WORK PLAN
PROJECT DESCRIPTIONS**

(EVALUATION CATEGORY 1 & 2 PROJECTS)

Recovery of Harbor Seals from EVOS: Condition and Health Status

Project Number:	95001
Restoration Category:	Research (new)
Proposed By:	University of Alaska, Fairbanks
Lead Trustee Agency:	ADFG
Cost FY 95:	\$172,800
Cost FY 96:	\$135,900
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harbor seal

INTRODUCTION

This proposal is written in collaboration with the inter-disciplinary and integrative marine mammal ecosystems program submission to EVOS. As outlined under the broad program direction, the goals of the combined collaborative projects are to investigate ecosystem wide questions addressing the recovery of marine mammal injured species, specifically, harbor seals. These issues include the direct impact of oil spills, human interactions, food, competition, climatic factors, disease and habitat loss. Under these guidelines, the enclosed proposal deals with the issues of body condition and health status of harbor seals with the resulting data applying directly to issues of disease, food limitation and the impact of oil.

In collaboration with other field teams, 30-40 harbor seals will be captured and temporarily held at sampling sites within and outside the EVOS area. Complete body morphometrics (to assess body condition) and samples of blood (to examine disease/health status) will be collected. Seals will be returned unharmed to the capture site and blood samples will be taken to the University of Alaska in Fairbanks for analysis.

Body Morphometrics. Using a large temporal and geographic data base currently held at UAF, the body morphometrics of the harbor seals will be analyzed and fit to models of body condition. For example, we have excellent data relating the length and girth of seals to their body mass. By fitting harbor seals to these curves, we can assess whether the animals are underweight (malnourished) or "normal". Additional factors, such as estimates of total body fat and body density are included in these assessments of condition. It is proposed that by comparing values for body condition from harbor seals collected before and after the EVOS event and by comparing data collected from animals inside and outside of the EVOS area, we can provide information as to whether this species, which is not recovering, appears to be physically sound.

Blood Chemistry: Samples of blood will be analyzed for over 30 indicators of "health". These tests will examine, among others, potential anemia, dehydration, organ function, tissue damage and oxygen carrying capacity. In addition, assays for hormonal balance and stress protein levels that are extremely sensitive to alterations in health status will be conducted. These data will be compared, on a temporal basis with samples collected before EVOS and on a geographic basis with control animals that were not impacted.

NEED FOR THE PROJECT

As a component of the marine mammal ecosystems proposal, this project deals with the health status/disease/body condition segment of harbor seal biology. To move towards the restoration of marine mammals, a multi-disciplinary, integrative approach is critical given the scope of the problem. Thus, certain components of the marine mammal ecosystems group will focus on habitat use and trophic level interactions, others on population studies and others on food resources. Any one agency cannot handle all components of such an intense approach. The University can provide the services and research for the health component through the Institute of Marine Science marine mammal physiology group. To move towards restoration, interactive projects, such as the one proposed here, must be carried out in collaboration with monitoring programs. That is, limited field programs that only contained a monitoring component or conversely only looked at individual animals would not be the most appropriate way to understand the impact of the EVOS event on injured species.

The premises and hypotheses of this project are simple: Either the EVOS impacted animals are different in their health status compared to non-EVOS animals, or they are not. If the species are compromised, then we will know some of the directions that would have to be followed towards potential restoration. If they are not compromised, then we will be able to focus our attention into other areas that may better explain their current recovery status.

PROJECT DESIGN**A. Objectives**

1. Capture 30-40 harbor seals at locations throughout PWS at 2-3 different times per year. This work will be in direct field collaboration with ADFG.
2. Hold animals for 1-4 hours during which time complete body measurements and blood samples will be collected.
3. Analyze body measurements via computer modeling and assay blood samples for health indicators.

B. Methods

Captures: This will involve procedures tested in the field and routinely utilized by ADFG. Basically, the seals are approached from sea on small boats while the animals are hauled out on beaches. A net is set across the beach and the animals move from the beach into to water when they see the boats. Animals are caught in the nets, moved onto the beach, tranquilized to facilitate the measurements and held until all sampling, attachment of diving recorders and recovery from anaesthesia are completed.

Body measurements: Linear and curvilinear length, girth at 7 locations and mass are collected from each animal. These are quickly and easily carried out in the field. Back at UAF, the data are fit into models of how length, girth and mass are related for harbor seals and animals are quickly placed above or below their predicted weight for size. In addition, estimates of total body fat will be collected from measurements of total body impedance (BIA). This method utilizes a quick assessment of body fat by measuring resistance across a set of electrodes placed at the head and tail of the body. Further estimates of body fat are taken from ultrasound measurements of blubber depth at half a dozen sites across the body. From all of these values, estimates of body density (i.e., relative fatness) can be evaluated.

Blood chemistry: Blood samples are measured in the field to assess the number of red cells in the blood (hematocrit), visualized under microscopes to examine the types of blood cells and then prepared for return to the lab. At Fairbanks, the samples are sent to a veterinary laboratory for assessment of "standard" health indices (such as cholesterol level, salts, and enzymes characteristic of tissue damage) and also analyzed at UAF for indicators of dehydration (water content), malnutrition (BUN, ketones), stress (haptoglobin), hormone imbalance (Angiotensin, ANP) and stress proteins (samples sent to collaborators at Stanford Research Institute). These data can then be compared to cataloged values for healthy seals to assess the status of the PWS seals.

It should be emphasized that the above methods are routine for the marine mammal group at UAF and that we conduct similar assays hundreds of times/year on seal and sea lion species from around the world. Thus, we have the expertise, the data bases and the consistency to best analyze these samples from the PWS animals.

C. Schedule

Capture dates: It is anticipated that captures of harbor seals will occur in the spring (April), summer (July) and fall (October) for both calendar years 1995 and 1996.

Analysis dates: Blood samples will be analyzed after each capture. Some of the assays are rapid and can be done within days for all samples, others take much longer. Body morphometric analysis is rapid and animals can be quickly assessed.

Report dates: The last predicted field season will be in the fall of 1996 and the final section of support will be to allow completion of analyses and publish reports. A final report will be submitted on 12/31/97.

D. Technical Support

Veterinary samples will be sent on a service agreement to veterinary facilities in Fairbanks. Stress protein samples will be sent to Stanford Research Institute for analysis. All other analytical processes will be carried out by UAF personnel. Boat and direct field support will be through our ongoing collaboration with ADFG.

E. Location

Harbor seals will be captured in the EVOS event area in central and southwest PWS.

PROJECT IMPLEMENTATION AND COORDINATION OF INTEGRATED RESEARCH EFFORT

As noted above, this project on the health of harbor seals, is submitted jointly as part of the marine mammal ecosystems program. This component is being run by the marine mammal physiology group at UAF. Other state agencies, federal agencies and universities will be in charge of other components of the project. UAF, ADFG and NOAA currently collaborate with each other on marine mammal biology projects in and around Alaska. This project expands and builds on that collaboration and extends the depth of the project to focus on the EVOS event.

FY 95 BUDGET (\$K)

Personnel	7.2
Travel	0.0
Contractual	153.0
Commodities	0.0
Equipment	0.0
Subtotal	161.0
Gen. Admin.	11.8
Total	172.8

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Harlequin Duck Abundance and Productivity in Western Lower Cook Inlet

Project Number:	95005
Restoration Category:	Monitoring (new)
Proposed By:	DOI
Cost FY 95:	\$40,500
Cost FY 96:	\$42,000
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Western Lower Cook Inlet from Redoubt Point to Sea Otter Point, including Tuxedni and Chinitna Bay
Injured Resource/Service:	Harlequin duck

INTRODUCTION

The purpose of this project is to establish baseline population parameters for harlequin ducks (*Histrionicus histrionicus*) in Western Lower Cook Inlet. This project will provide information on harlequin duck distribution, abundance, productivity, and habitat use that will assist in restoring harlequin duck populations in the Gulf of Alaska.

NEED FOR THE PROJECT

There is no existing information concerning harlequin ducks in Western Cook Inlet. Random observations made during routine coastal patrols and reconnaissance surveys following the 1989 *Exxon Valdez* oil spill suggest that this region supports a substantial breeding population of harlequin ducks. Although the project site occurs within the *Exxon Valdez* Spill Area, it has been assumed that harlequin duck populations and habitat were not impacted.

Knowledge of breeding harlequin duck numbers and reproductive performance on the northwestern edge of the spill zone will provide a useful reference against which recovery rates in Western Prince William Sound can be measured. Full restoration of this species may require knowledge of how populations are performing in undisturbed breeding habitats.

In addition, results of this project can be used to direct management actions that protect or maintain harlequin duck populations within Western Lower Cook Inlet. Some coastal and riparian habitats within this region could be adversely impacted by logging, mining and residential development on private inholdings. Information on harlequin duck distribution and habitat requirements is necessary to guide land acquisition or protection efforts within riparian corridors.

PROJECT DESIGN

A. Objectives

Determine distribution, abundance, productivity, and habitat use of harlequin ducks (population parameters will be expressed as breeding adults and juveniles/linear mile of coastline).

B. Methods

Numbers of adult harlequin ducks will be estimated bi-weekly from 1 May to 15 June in tidal estuaries and coastal waters before they ascend the rivers to breed. From 15 July to 30 September bi-weekly surveys for adults and broods will be used to measure production. Population/production surveys will systematically sample coastal and intertidal habitats between Redoubt Point and Sea Otter Point, and large near-coastal lakes such as Crescent and Hickerson. Coastal harlequin population/production surveys will be conducted from a 22 foot aluminum skiff powered by twin 50 hp outboards. A skiff operator will pilot the vessel near the coastline, islands and off-shore rocks, and in intertidal estuaries. One or more observers will use 8-10X binoculars to determine numbers, sex, and age of all birds sighted. Habitat descriptions of breeding streams, including vegetative, hydrologic, and topographic characteristics as described by Patten, will be made from 1:12,000 scale aerial photographs obtained in 1993 and selective ground surveys.

C. Schedule

Early (May-June) and late summer (July-September) surveys will be used to measure reproductive effort and performance of resident harlequin ducks. Habitat descriptions will be made during July and August. Data analysis and report preparation will be completed in November.

D. Technical Support

Computer services and other technical support will be provided by Lake Clark National Park.

E. Location

The project will include near-coastal waters, rivers and lakes between Redoubt Point and Sea Otter Point in Western Lower Cook Inlet. No communities will be affected by the project.

PROJECT IMPLEMENTATION

The Lake Clark National Park field headquarters at Port Alsworth would implement 100% of the this project. Park biologists have the technical expertise and logistical support to conduct this project in the most timely and cost-effective fashion. Local knowledge of the coastline, field work conditions, and the seasonal use patterns of harlequin ducks is pivotal to the success of the project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The Alaska Department of Fish and Game, Division of Wildlife Conservation and U.S. Fish and Wildlife Service will collaborate in this project. Survey dates and procedures will conform to those used by the U.S. Fish and Wildlife Service and Alaska Department of Fish and Game to assure direct comparison of results with other study sites. Because site-specific variations may occur in the chronology of harlequin breeding, survey dates in this project span a broader period than those used in Prince William Sound.

FY 95 BUDGET (\$K)

Personnel	12.0
Travel	8.5
Contractual	13.0
Commodities	2.0
Equipment	2.0
Subtotal	37.5
Gen. Admin.	3.0
Total	40.5

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Archaeological Site Restoration -- Index Monitoring

Project Number:	95007A
Restoration Category:	Monitoring (continuation of 94007)
Proposed By:	DNR
Cooperating Agencies:	USFS, DOI
Cost FY 95:	\$386,300 (includes \$191,700 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$193,200
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Oil spill area
Injured Resource/Service:	Archaeological resources

INTRODUCTION

Damage to archaeological sites as a result of cleanup activities after the *Exxon Valdez* Oil Spill has been amply documented in damage assessment studies performed since the spill. Sites vandalized since the spill have been monitored and plans developed to restore the damages at the studied sites. Monitoring of damaged sites as a gauge of vandal activities in the spill area was identified as a primary strategy for site restoration during fiscal year 1995 (FY95). The monitoring will continue and extend beyond the documentation of vandalized sites investigated under project 94007, Site Specific Archaeological Restoration

Closeout of local community interviews to compile local preservation plans and needs plus report completion for Project 94007 will be a component of Project 95007A.

NEED FOR THE PROJECT

Evidence of vandalism dropped dramatically after 1989, probably reflecting the more effective archaeological constraint system that had been put into place by the participating agencies, with the cooperation of Exxon Corp., by the late summer of 1989. This apparent reduction in vandalism was unexpected and at first suggested that continued vandalism related to the *Exxon Valdez* spill event might not be a significant future concern. However, based on what we know

about the behavior patterns of archaeological looters, the activity focus of vandals may have shifted (or will shift) from general prospecting to a more focused pattern during the initial "prospecting" phase, or simply observed by more discrete potential looters engaged in cleanup operations in the post-1989 era. Artifact hunters are most likely to act on the opportunities presented by this knowledge in the next 15 years while their memories remain fresh; thereafter, the threat should gradually drop as the information loses "immediacy" and specificity.

Local communities have identified repeatedly the need for a program to preserve the injured heritage of the people and a coordinated plan to accomplish that goal is the aim of the closeout for 94007.

PROJECT DESIGN

A. Objectives

Archaeological monitoring of archaeological sites injured by the spill or spill related activities will target a small number of sites which are determined to represent those that are most vulnerable to looting. Those sites will serve as a gauge for levels of vandalism in the spill area. Compilation of local heritage preservation needs into one coordinated plan are a closeout objective for 94007.

B. Methods

A strategy was identified during a 1994 restoration workshop of designating 3 or 4 index sites or sites critically vulnerable to looting which will be monitored on an annual basis. A second group of 4 sites will be selected for monitoring biannually as a check over a broader area. The second group of sites may vary over time in order to maintain flexible response to new information such as fresh reports of vandalism or new findings on patterns of looting. The second group of sites provides a cross-check to monitoring data collected at the index sites. Focusing annual monitoring on 4 index sites and using a 2-year monitoring schedule on the additional 4 sites, expenditures will be significantly reduced while maintaining continuity of tracking levels of vandalism over the years. Vulnerability to looting will be the primary criteria of selection with managerial jurisdiction a secondary concern. One or two of these sites will also be selected for continued hydrocarbon monitoring so the behavior and effect of oiling can be observed over the long term in archaeological deposits. The closeout plan for FY94 data will consider federal, state and private programs in a single document.

C. Schedule

Project proposal reviewed in Public Review Document.....	August, 1994
Trustee Project Approval.....	November, 1994
Completion of interviews in local communities.....	November, 1994
Submittal of draft heritage plan for local comment.....	January, 1995
Detailed Work Plans submitted.....	January 1, 1995
Final Heritage Plan.....	May, 1995
Fieldwork.....	May-August, 1995
Draft Report.....	October 1, 1995
Final Report.....	January 1, 1996

D. Technical Support

The only technical support will be provided by commercial radiocarbon laboratory and a lab capable of conducting the required chemical testing.

E. Location

The sites will be located throughout the spill area.

PROJECT IMPLEMENTATION

This project will be implemented by agency archaeologists meeting the professional qualifications specified under the Secretary of the Interior's Guidelines for Archaeology and Historic Preservation.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will be coordinated with the Traditional Knowledge Transfer Project proposed for Trustee funding in FY95. It will not mesh well with other projects although logistic arrangements will be coordinated with projects within each agency.

FY 95 BUDGET (\$K)

	FY 94 Report*	FY 95 Work**	Total FY95 Budget
Personnel	80.7	97.5	178.2
Travel	1.5	38.0	39.5
Contractual	90.1	34.1	124.2
Commodities	1.0	7.8	8.8
Equipment	0.0	0.0	0.0
Subtotal	173.3	177.4	350.7
Gen. Admin.	18.4	17.0	35.4
Total	191.7	194.4	386.1

* Includes Site Specific Restoration Report and Community Protection Plan

** Includes Index Sites Monitoring

Site SEW-488 Archaeological Site Restoration

Project Number:	95007B
Restoration Category:	General Restoration (continuation of 94007)
Proposed By:	USFS
Lead Trustee Agency:	ADNR
Cooperating Agencies:	USFS
Cost FY 95:	\$116,000
Cost FY 96:	\$16,100
Total Cost:	\$132,100
Duration:	2 years
Geographic Area:	Knight Island, Prince William Sound
Injured Resource/Service:	Archaeological resources

INTRODUCTION

The Louis Bay Lamp Site, SEW-488, was discovered during the *Exxon Valdez* Oil Spill Cleanup Program. This site has yielded dates for human occupation ranging from 600 BP to 3,400 BP. Injury to the site consists of oiling during high pressure water treatment and unmonitored cleanup activities. Although this project was funded in FY94, objections to the work by one of the interested parties has halted current field efforts.

NEED FOR THE PROJECT

Preliminary testing indicates the site has the potential to reveal an extensive sequence of occupational layers interspersed by beach deposits. This project will enhance the scientific and cultural understanding of early occupants of the Sound as well as ensure the preservation of the site for further investigation or protection. It must be assumed that this is the only site that can provide the kind of information already documented to exist there. Without its preservation through halting further impacts, that information (and the cultural values it embodies) will be irretrievably lost. Without stabilization of the deposits from further deterioration, the exposed cultural materials provide a lure for site destruction through vandalism. The stabilization will, therefore, help protect the site from human as well as natural impacts. Data collection and

analysis will allow evaluation of the site for listing on the National Register of Historic Places. The resulting information will provide significant insights into the prehistoric habitation of Prince William Sound for subsequent interpretation and educational programs.

PROJECT DESIGN

A. Objectives

1. Ameliorate and halt the deterioration and destruction of the site.
2. Protect and preserve the remaining cultural deposits.
3. Add to the scientific and cultural knowledge of the prehistory of the Prince William Sound.

The results of the project will include separate reports geared appropriately for professional archaeologists and for members of the general public.

B. Methods

The site is about 75 m long by 30 m wide, with a depth exceeding one m. Excavation of about 10 cubic m along the eroding site edge is proposed, with 6 subsequent 50 cm tests to more accurately define the boundaries of the site. Additional excavation of eight 1 m squares in the main body of the site would provide an adequate sample of the site to augment preliminary testing already accomplished.

Following the procedures set forth in pertinent legislation and guidelines, the project will mitigate the damage to the archaeological site through data gathering and physical restoration/stabilization. Final physical restoration will include backfilling, stabilization and/or revegetation of affected areas and archaeological tests.

The research design and field arrangements will be coordinated by a GS-11 (or equivalent) archaeologist/principle investigator (PI). The field crew will consist of the PI, one GS-9 (or equivalent) archaeologist and two GS-7 (or equivalent) archaeologists. The GS-11 archaeologist will coordinate analysis and report production. Reports will be in formats designed for both professional and public audiences.

All or parts of the project may be contracted out through the Forest Service. Sole source contracts for the work may be allowed if suitable "8A" contractors submit proposals. If no 8A contractor is so employed, contracting will be through established competitive means as established in Forest Service regulations, policy and guidelines.

A checklist of milestone dates will be kept by the Principle Investigator and the Forest Archaeologist for the Chugach National Forest. The quality and timeliness of field work, analysis, and report production will be monitored by the Forest Archaeologist.

C. Schedule

January 1, 1995	Start of consultation under the National Historic Preservation Act and the Native American Graves Protection and Repatriation Act and preparation of work plans and research designs. Continuation of logistical and personnel planning.
July 5, 1995	Start of field work of site restoration work.
September 30, 1995	Completion of interim field report to USFS.
December 31, 1995	Completion of draft final report to USFS.
April 30, 1996	Completion of review by USFS and delivery to the ADNR.

D. Technical Support

The project requires qualified field and laboratory personnel, C14 dating, analysis of soils, faunal remains, artifacts and other remains, and permanent curation of collected material.

E. Location

The project site is located on Knight Island in Prince William Sound.

PROJECT IMPLEMENTATION

USFS will implement this project. This will be a continuation of restoration work conducted by USFS personnel at this site in FY 94. Data will be collected in a manner compatible with other archaeological restoration work according to an approved work plan.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Data gathering and analysis will be coordinated with project 95055 which entails development of a prehistoric biological data base for the EVOS area.

FY 95 BUDGET (\$K)

Personnel	67.0
Travel	2.2
Contractual	32.0
Commodities	1.5
Equipment	1.0
Subtotal	103.7
Gen. Admin.	12.3
Total	116.0

Trophic Dynamics and Energy Flow: Impacts of Herring Spawn and Sea Otter Predation on Nearshore Benthic Community Structure

Project Number:	95009C
Restoration Category:	Research (new)
Proposed By:	Institute of Marine Science, UAF
Lead Trustee Agency:	USFS
Cooperating Agencies:	ADFG
Cost FY 95:	\$217,300 (includes \$74,510 in data analysis and report writing costs)
Cost FY 96:	\$291,800
Total Cost:	Unknown
Duration:	3-5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sea otter, intertidal and subtidal organisms

INTRODUCTION

Nearshore foodwebs are only partially understood and undoubtedly vary from site to site, especially with regard to source and magnitude of energy flow. The presence or absence of certain species or web connections, and the relative strengths of interactions common to most sites, are likely dependent upon source and magnitude parameters. Nearshore energy inputs are typically a mixture of local production, e.g. kelps, seagrasses and resident phytoplankton, and imported production, usually in the form of phytoplankton distributed by the overall current regime of the region.

Each spring, schools of Pacific herring enter Prince William Sound to deposit eggs on rocks, kelps and seagrasses in intertidal and shallow subtidal habitats. The herring, as well as some intertidal and subtidal organisms, have been identified as EVOS injured resources. The arrival of the herring at spawning sites marks the onset of a major, imported energy pulse at those sites. Not only are the eggs an energy source, but so are fish carcasses and fecal material as well as fecal inputs from mammalian and avian predators that track the herring. Herring densities and spawn deposits have been reduced since the EVOS and intertidal and subtidal communities have only partially recovered.

We propose to investigate the impact of herring spawning activities on intertidal and shallow subtidal foodwebs by comparing regular spawning sites with non-spawning sites. Each year, the Alaska Dept. of Fish and Game monitors the herring migration, spawning sites and the amount of spawn produced. We will cooperate with the ADFG in selection of two study sites based upon dependability of herring return and estimated magnitude of energy contribution. A non-herring site in the vicinity of each herring site will be carefully chosen for comparison. Candidates for the two pairs are northern Montague Island paired with northern Green Island and Bidarki Point paired with southern Bligh Island. Northern Montague and Bidarki Point are the most consistent sites of herring spawn deposition over the past ten years, while there has been little or no spawning activity at the other two sites during the same period.

In addition to the herring energy input work (bottom-up), we will investigate the impact of a dominant predator, the sea otter, on intertidal and shallow subtidal communities (top-down). Otters tend to be patchily distributed in the nearshore zone (pers. obs.). Thus, some areas are heavily utilized for foraging and others are not. Because sea otters do not have an insulating blubber layer, they depend upon their fur coat and a high metabolic rate to maintain body temperature. Consequently, daily consumption of benthic organisms by otters typically amounts to 20-30% of their own body weight. While sea otter impact on specific prey species can be locally devastating, other components of the community are likely affected also. For example, prey species such as butter clams are also utilized by the sunflower star *Pycnopodia helianthoides*. As butter clam densities are reduced, the seastar population may decline also. Sea otters are also known to prey on benthic predators such as seastars and octopus, and on sea urchins which are usually considered grazers but also scavenge and are sometimes predatory. Thus, otters impact nearshore communities at different trophic levels. In order to gain an understanding of sea otter influence on overall community structure, a heavily utilized region will be compared with Herring Bay, where otter densities are low and we have considerable information on the intertidal community. The sea otter utilization sites will be chosen in consultation with researchers working on sea otters. Initial indications are that regions on the north sides of Montague and Green Islands being considered for the herring work (see above and multi-disciplinary umbrella proposal) will also be suitable sea otter utilization sites, possibly resulting in considerable savings.

This proposal specifically addresses the contribution of marine invertebrates to food web complexity (both as predators and as prey), energy transfer and community structure at matched sites as a component of the multi-disciplinary nearshore ecosystem study, "Trophics and Community Structure in the Intertidal and Shallow Subtidal". Other components of the collaborative study will investigate nutrient supply, primary production and ecology of benthic plants, and the role of highly mobile (vertebrate) predators in the nearshore environment.

NEED FOR THE PROJECT

Pacific herring, intertidal organisms (some), subtidal organisms (some) and sea otters are considered to be not recovering from the EVOS. These groups are the main focus of this research proposal. Determining the course of energy flow through a community should reveal important structuring mechanisms. Understanding structuring mechanisms is necessary to distinguish between spill-related and natural changes in communities and to predict recovery rates and acceptable end-points. In cases of non-recovery, this knowledge may be critical. For example, normal mass spawning of herring probably swamps out local predators on both fish and eggs. With a greatly reduced spawning population, the relationship may be reversed, with fish, eggs and larvae so heavily preyed upon by the concentration of predators that recovery is further inhibited. Determining the effect of the herring-related energy pulse on the nearshore community should provide insights into how the source (type) and magnitude of energy inputs impact community structure and dynamics. Do kelp recruitment success and growth rates increase due to the enhanced nutrient (feces, carcasses, failed eggs) supply, resulting in damped onshore water motion and reduced food supply for filter feeders such as mussels and barnacles, and reduced larval supply for recruitment of intertidal organisms? If primary production is enhanced, will local grazer densities increase and will grazers such as sea urchins switch to herring eggs when available? Numerous other examples could be given. The herring-based energy pulse in local habitats may serve as a tracer, revealing important aspects of herring biology and nearshore community ecology.

With regard to sea otters, do they so broadly depress invertebrate prey populations that nearshore benthic communities are recruitment driven? Is the distribution of sea otters dependent upon the availability of certain prey species? Were densities of key members of the prey-species list reduced by the oil spill? Does the presence of otters invariably result in alternate communities (e.g. kelp vs no kelp via predation on sea urchins) as suggested in the literature. Do non-prey species increase in abundance when prey populations are depressed? For example, do infaunal polychaete worm populations increase when butter and steamer clam densities are substantially reduced? And can the worms prevent recolonization by clams through predation on newly settled clam larvae or juveniles? To what extent can varying concentrations of sea otters be sustained by the nearshore benthic community? Again, there are many important questions surrounding the role of sea otters in the nearshore environment and tracking energy flow should provide a framework for investigating non-recovery of both the otters and impacted components of the intertidal and subtidal communities.

PROJECT DESIGN

The general objectives of the herring spawn deposition study are given in the over-arching proposal, *Trophics and Community Structure in the Intertidal and Shallow Subtidal*. Briefly, three major hypotheses are presented: 1) localized energy inputs related to the spawn deposition increase productivity, standing crop and diversity; 2) mobile predators initially attracted by the spawn activities reduce standing crop and diversity by preying on less mobile resident species; and 3) the herring-related energy inputs have no lasting effect on the

community. The objectives of the study relative to sea otter site utilization are to examine the impact of sea otter predation on benthic community structure, including changes in the food web and major energy pathways.

A. Objectives

Specific objectives for 1995 include:

1. Establish study sites based on visits to candidate sites by the interdisciplinary team. See umbrella proposal for discussion of criteria.
2. Design interdisciplinary nested sampling schedules to examine site characteristics at several scales.
3. Within each focal site, measure abundance and distribution of specific intertidal and shallow subtidal invertebrates, particularly those preying on herring eggs, preyed upon by sea otters or having a major role in energy transfer or community structure.
4. Conduct stable isotope analyses (C, N and possibly S) on tissue samples of invertebrates as part of the overall effort to develop food web models at the study sites. Criteria for selecting species will be same as in No. 3.
5. Determine which invertebrates prey on herring eggs.
6. Determine which invertebrates prey on invertebrates in No. 5. Do the species change with habitat type?
7. Determine if benthic secondary productivity is enhanced by fecal inputs from herring and predators drawn to the spawn site.
8. Determine if mobile predators drawn to the spawn sites have a negative effect on the local invertebrate community. Rather than benefitting from the energy pulse, resident invertebrates may be subjected to unusually intense predation by the concentration of mobile predators. For example, groups of gulls have been observed vigorously attacking the large seastar, *Pycnopodia helianthoides*, during low tides. Seastars are ripe in the spring, making them an energetically rewarding prey item.

Objectives 1 and 2 will be completed in 1995. Studies will be initiated in FY95 to address the other objectives but will extend into FY96 and FY97 before completion.

B. Methods

As indicated in the objectives section, sites will be selected jointly by the principal investigators after visiting the candidate sites and consultation with other researchers working on herring spawning activities and sea otters.

Densities of herring egg predators, sea otter prey species and species having a significant role in energy flow at the study sites will be determined using a nested sampling design integrated with other components of the study. To the extent possible, densities of target species will be determined in the field. Distributions will be related to substrate and habitat type, particularly with regard to those utilized by herring for egg deposition and otters for foraging.

Tissue samples of the species of interest will be collected and analyzed for carbon and nitrogen stable isotope ratios to investigate energy flow pathways and relative strength of food web linkages. Stable isotope data on herring eggs will be provided by E. Brown (ADFG). In addition, direct observations of feeding activities will be made and quantified where possible. Gut contents or fecal material of freshly collected invertebrate predators, including suspected herring egg predators, will be examined (undigested material and hard parts can often be identified and our laboratory has considerable experience with this type of work). Feeding experiments will be conducted at the University's Kasitsna Bay Laboratory to determine prey choice of certain invertebrate predators, particularly potential herring egg predators such as *Strongylocentrotus droebachiensis* (green urchin), *Pycnopodia helianthoides* (sunflower seastar), *Leptasterias hexactis* (seastar), *Fusitriton oregonensis* (hairy triton), *Nucella* spp. (whelks), and the common crabs *Cancer oregonensis* and *Telmessus cheiragonus*. For example, feeding experiments will be conducted with amphipods. Preliminary examination of benthic quadrat samples collected by ADFG at herring spawn sites indicates that amphipods (6 families) are abundant, including lysianassids which are well known predators and scavengers. *Leptasterias hexactis* and juvenile *P. helianthoides* also occurred in the quadrat samples. Field manipulations (transplants, enclosures, exclosures, etc.) will not be attempted in 1995 but may be included in study plans for subsequent years based upon 1995 results.

Densities and size-frequency distributions of major sea otter prey species (*Saxidomus giganteus*, *Protothaca staminea*, *Mya truncata*, *M. arenaria*, *Macoma* spp., *Telmessus cheiragonus* and mussels) will be determined at the low and high otter usage sites.

At soft-bottom herring spawn sites, sediment samples will be collected for CHN analyses in comparison with samples from non-spawn sites. Collections before, during and after the spawning activity should reveal whether there is organic enrichment through transport of herring and herring predator fecal material. Densities of infaunal organisms will also be compared between sites.

C. Schedule

- Winter, 1995: Personnel selection, purchase supplies and materials, team planning workshop
- Spring, 1995: Site visits and site selection, preliminary tests of experimental protocols, initiate study (especially at herring spawn sites), begin feeding studies and isotope analyses
- Summer, 1995: Data collection and sampling at study sites, feeding studies, isotope analyses, preliminary examination of data

Sampling will be conducted quarterly. Report writing will be ongoing throughout the year with annual report submission in April of each year.

D. Technical Support

Stable isotope and CHN analyses will be conducted at the Institute of Marine Science, UAF. We are experienced at conducting these analyses. Sufficient replicate samples will be analyzed to meet statistical requirements. Computer services and data management will be provided by IMS.

E. Location

The work will be conducted in Prince William Sound. Study sites under consideration are northern Montague Island, northern Green Island, Bidarki Point, southern Bligh Island and Herring Bay. Reasons for considering these sites were presented in the Methods section.

PROJECT IMPLEMENTATION

This project should be implemented by the U.S. Forest Service through the various cooperating agencies.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is part of a coordinated study to be conducted by scientists from the University of Alaska, Prince William Sound Science Center and the U.S. Forest Service. The herring related work will be done in close collaboration with ADFG, including some data sharing and sample collecting. The work will also be coordinated with vertebrate predator studies in the NBS program. Collaboration will also occur with the SEA study through physical oceanography, herring, nearshore fish and avian predation studies.

FY 95 BUDGET (\$K)

Personnel	124.5
Travel	10.2
Contractual	20.0
Commodities	6.5
Equipment	15.0
Subtotal	181.1
Gen. Admin.	36.2
Total	217.3

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Survey and Experimental Enhancement of Octopuses and Chiton in Intertidal Habitats

Project Number:	95009D
Restoration Category:	Research (new)
Proposed By:	Prince William Sound Science Center and West Coast National Undersea Research Center
Lead Trustee Agency:	USFS
Cost FY 95:	\$188,900
Cost FY 96:	\$177,000
Total Cost:	Unknown
Duration:	2-5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Subsistence, intertidal organisms

INTRODUCTION

Nearly 90% of the residents of Tatitlek, Chenega Bay, and Cordova used marine invertebrate subsistence resources prior to the *Exxon Valdez* oil spill. Some portion of these marine invertebrates are octopus, traditionally harvested from their dens in the intertidal zones by subsistence users. Subsistence users in Prince William Sound have noted apparent declines in octopus and other species (e.g., gumboot chiton) since 1989. Although no connection to damage by oil has been established, the decline of these mollusks following EVOS further reduces subsistence resources available for residents in the EVOS affected area. This proposal is for funds to survey intertidal octopus and gumboot chiton densities at several sites, provide information on habitat use and distribution for these species, and explore the potential of artificial dens as a cost-effective survey technique and as a way to enhance local octopus density.

Oil from the *Exxon Valdez* had a large impact on organisms in intertidal areas. As populations in these areas respond to this disturbance, the composition of intertidal communities may change dramatically. This will affect all species using the intertidal, not only those documented as injured by exposure to the oil. Changes in the abundance of many species are to be expected in these circumstances. In addition to mollusk declines, noted changes include, among many others, local declines in sea otter abundances and increases in opportunistic algae.

Octopuses and chitons are both important prey of sea otters in areas where high otter density has persisted over several years. Declines in octopuses may therefore be a result of changes in sea otter density over recent decades. Alternatively, if octopuses were adversely affected by *Exxon Valdez* oil, their decline may result in less food for recovering otter populations. Octopuses are also efficient predators on other invertebrates and small fish in the intertidal, and may be an important element in the intertidal trophic structure.

The extent, severity, and cause of octopus declines are not known. Nor is it known if changes in the abundance of these mollusks will adversely affect the recovery of other intertidal species. Without information of this type, the course of recovery of octopus in the intertidal cannot be predicted, nor can this resource be managed as effectively as possible.

NEED FOR THE PROJECT

Octopuses and chitons are included as injured, non-recovering species under the general headings of subtidal organisms and intertidal organisms. Subsistence use of these resources in Prince William Sound has resulted in the knowledge that these species have declined in apparent abundance. The extent, severity, and cause of these declines are unknown, but comprise a part of the decline in subsistence services.

This project proposes a survey of these species to initially assess the extent of declines, as well as a test of potential monitoring and restoration of octopus through artificial den construction. Information from this study will be conveyed to subsistence users.

PROJECT DESIGN

A. Objectives

The overall purpose of this project is to assess site-to-site variability in octopus density as indicated by use of natural intertidal dens, to measure habitat associations of octopus in the intertidal, and to test artificial den placement as a means of 1) surveying octopus densities and 2) enhancing octopus densities. As a secondary goal, we will survey chiton density during octopus surveys.

For 1995, sampling will be focused at the sites of the "Trophics and community structure in the intertidal and shallow subtidal" projects, in order to share costs with those projects. An additional survey site will be identified that has been harvested in recent years. Once successful techniques are developed from the 1995 work, sites designed to monitor octopus in other subsistence areas may be added.

1. Consult with subsistence users in Tatitlek to improve study design, identify a suitable survey site with a history of harvest, and recruit collaborators. Tatitlek is chosen here because of its proximity to TCSISS sites identified for sampling.
2. Conduct seasonal surveys of octopus use of natural dens in intertidal areas during low tides. Measure distribution and density of gumboot chiton in the same areas.
3. Test short-term placement of artificial octopus dens as a technique to survey local octopus density.
4. Test long-term placement of artificial octopus dens as a technique to enhance local octopus density.
5. Examine octopus distribution and density in light of results from this and other TCSISS projects to formulate specific hypotheses about factors constraining octopus abundance at sampling sites.

B. Methods

1. In collaboration with Jody Seitz (SEA Planning and Communications), involvement of subsistence users of octopus will be solicited for the goals stated above.
2. At low tide, foot surveys will be conducted along transects for occupied intertidal octopus dens. Potential and occupied den locations along a survey will be noted to estimate the proportion of den sites that appear to be occupied. Surveys will be stratified according to habitat types identified in the "Mobile Foragers" and other projects. At each location, local octopus density will be assumed constant over a period of a few days, and repeated surveys will be used to estimate variance in the sampling technique.
3. Octopus are known to use artificial structures as temporary den sites. We will design artificial dens and place them in the intertidal and shallow subtidal to evaluate the placement of artificial dens as an octopus survey technique. Octopus should use the dens, and artificial den occupancy will then serve as an indicator of local octopus density, much as a trapping grid can indicate rodent density in a grassland.
4. If suitable den sites are limiting to octopus, the addition of permanent dens to areas with few octopus should enhance octopus density. We will artificially increase den availability in restricted areas and evaluate the cost-effectiveness of this technique to locally increase octopus density.

5. If dens are known to be utilized, yet do not increase octopus density over time, this strongly suggests that octopus density is limited by prey availability or recruitment, and not by den availability or predation. Results from this survey and other projects will be used to develop testable hypotheses about the cause of apparent declines in octopus and/or gumboot chiton.

Den selection as a survey tool presents several challenges to the researcher. First, artificial dens must be designed to be suitable, or octopuses will not utilize them. However, it is relatively simple to design artificial dens that octopuses will inhabit, the requirements being that the den be opaque and have an enclosed space with a narrow opening. In addition, because sea otters will prey on octopuses denning in containers such as aluminum soda cans, we will make artificial dens which resist attack by sea otter. Second, if artificial dens are preferred to natural dens, octopus may abandon traditional dens to use artificial ones. In the extreme, this may mean that we find 100% occupancy of artificial dens over a wide range of local octopus densities. However, this effect will be clearly discernable from the survey results, and experimental design can be manipulated (design and density of artificial dens) to minimize it. Further, experiments with artificial den placement along census transects will be used to estimate octopus preference for artificial over naturally-occurring dens. Finally, if additional dens successfully enhance octopus densities, we must evaluate den placement as a survey technique in light of the knowledge that den placement increases octopus use of the area. When using dens to estimate local octopus density, this effect will be minimized by the limiting the duration that dens are in the water. Over the short term, artificial dens are likely be occupied by octopus already in the area, indicating local density.

Artificial dens may enhance local octopus density under two conditions: first, if den availability limits recruitment of juvenile octopus to an area; and second, if predation limits octopus densities and den availability limits predation rates on octopus. Dens will fail to enhance octopus density if den availability does not limit recruitment, does not limit predation rates or if neither recruitment nor predation rates limit octopus densities. Hence, results of experimental den enhancement will guide the formulation of specific hypotheses about octopus declines.

C. Schedule

Winter '95:	Personnel selection and equipment procurement. Site visits and site selection, laboratory design of artificial dens, preliminary tests of experimental protocols. Initiate visits and collaboration with subsistence users of octopus and chiton.
Spring '95:	Foot and artificial den surveys; habitat mapping. Experimental assessment of den preference.
Summer '95:	Foot and artificial den surveys; habitat mapping. Experimental assessment of den preference. Experimental test of artificial dens as octopus enhancement tool. Preliminary examination of data.
Sept-Oct '95:	Additional surveys
Nov 30 1995:	Draft report
Jan 30 1996:	Final report

D. Technical Support

In order to meet the stated goals, this project will need access to community knowledge of local harvest sites and site history. This will most likely be solicited from Tatitlek.

E. Location

This work will be conducted in Prince William Sound. Specific focal sites under consideration are northern Montague Island, northern Green Island, Bidarki Point, southern Bligh Island, and Herring Bay.

PROJECT IMPLEMENTATION

This project should be implemented by the U.S. Forest Service through the various cooperating agencies.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is part of the "Trophics and Community structure in the intertidal and shallow subtidal" program and will share logistics, personnel and study sites with other projects. Data and results will be shared among these projects. Each project therefore benefits from additional knowledge of a sampling site that would not otherwise have been collected.

This project shares a goal, that of understanding factors constraining a predator's use of habitats, with the project "Community structure of mobile foragers using the nearshore". Both projects will share a principal investigator (D. Scheel) and both will rely upon the same logistics for sampling.

Air and boat transportation necessary to get researchers to remote locations in PWS will be shared with other projects having similar needs.

FY 95 BUDGET (\$K)

Personnel	6.6
Travel	3.3
Contractual	147.5
Commodities	0.0
Equipment	0.0
Subtotal	157.4
Gen. Admin.	31.5
Total	188.9

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Killer Whale Monitoring in Prince William Sound, Alaska

Project Number:	95013
Restoration Category:	Monitoring (new)
Proposed By:	North Gulf Oceanic Society
Lead Trustee Agency:	NOAA
Cost FY 95:	\$113,700
Cost FY 96:	\$0
Total Cost:	Unknown
Duration:	Alternating years until recovery
Geographic Area:	Western Prince William Sound
Injured Resource/Service:	Killer whale

INTRODUCTION

Baseline population information based on photoidentification was collected by members of the North Gulf Oceanic Society (NGOS) prior to the EVOS. This data was used for damage assessment following the EVOS. The EVOS Trustee Council funded this work in 1989, 1990, and 1991. Damage assessment fieldwork for Prince William Sound was completed, and the data was analyzed, and published by NGOs under contract to the National Marine Mammal Laboratory. A total of 13 whales were lost from AB pod (initially 36 whales) between March 1989 and June 1990. Through recruitment the pod increased from 23 whales in June 1990 to 26 whales in 1993, it will require years for complete recovery. Nine whales in the AT1 transient group have not been photographed since 1989. Because immigration and emigration between transient groups does occur, we cannot be certain these missing whales are mortalities (except for one which was identified dead on a beach in 1990). However, we strongly suspect that they are dead. As a result of these findings, killer whales (*Orcinus orca*) have been listed by the EVOS Trustee Council as a damaged but recovering resource.

We propose to continue a monitoring program of resident and transient killer whales in Prince William Sound and to interface this program with proposed ecosystem studies. The program will focus on the population dynamics of AB pod and the AT1 group in relation to other resident and transient groups that use Prince William Sound.

NEED FOR THE PROJECT

Without careful monitoring of the damaged/recovering killer whale population, it will not be clear whether recovery has occurred. Because killer whales demonstrate a low reproductive rate long-term monitoring is necessary to clearly establish that recovery has or has not occurred. Careful analysis may identify problems that might inhibit recovery. Although AB pod appears to be recovering at this time, the status of the AT1 group is uncertain and should be monitored as well. The dynamics of these groups should be judged relative to the changes within the other frequently encountered pods. This necessitates a thorough census of all pods that regularly use the study area.

PROJECT DESIGN

A. Objectives

1. To photographically identify resident and transient killer whale pods in Prince William Sound.
2. To map population dynamics within all pods and monitor recovery or lack of recovery of injured groups.

B. Methods

Methods will be similar to those used by the NGOS to monitor killer whales in Prince William Sound for the past ten consecutive years. Photoidentification of each individual in each pod/group will be the primary tool. Photographic negatives will be analyzed using a photographic database that spans ten years. Identities of each whale that appears in every frame of usable film will be recorded and stored in VAX computer system. Final analysis and assessment will follow Matkin et al.

C. Schedule

Monitoring should occur in 1995 and at least every other year thereafter until full recovery is demonstrated (only 1995 is budgeted here). Field work will occur in July/August/September of 1995. A total of 90 vessel days will be spent in the field. Data analysis will occur in October and November. A draft report will be submitted by late December followed by a review period of two months. The final report will be submitted by April 1996.

D. Technical Support

The NGOS owns or will lease all equipment necessary for the successful completion of the project. A frame by frame analysis of photographic data will be computerized and archived with a copies supplied to the National Marine Fisheries Service and the Prince William Sound Science Center. NGOS has archived all photographic data collected since 1984 in an established computerized format.

E. Location

Field work will center in southwestern Prince William Sound. Vessels will be operate from Chenega Village and dock space rented from the Village Council. Fuel will be stored at Port San Juan and Chenega Village. (We currently have a fuel storage agreement with Port San Juan and Chenega). As in the past, close contact will be kept with tourboat and recreational boaters in the area. An observer's network which exchanges information on whale sightings has been maintained for 10 years in western Prince William Sound.

PROJECT IMPLEMENTATION

Accurate long-term monitoring is essential to determine recovery of this injured resource. The proposed project complements long-term systematic research projects begun by the North Gulf Oceanic Society 1983. The methods employed in the proposed work and the historic database essential for interpretation were developed by NGOS. Data collection has been supervised by the same individuals and photoidentifications made by the same individuals from 1984 to 1994. During that ten year span, over 50,000 frames of film have been examined and each whale in each usable frame of film identified. The validity of the photoidentifications has been tested independently and found to be accurate. The NGOS maintains the specific equipment (boats, cameras, lab equipment, etc.) and expertise to continue this project in a consistent and cost effective manner.

This is a significant opportunity for the Council to fund a project conducted by a private Alaskan entity, staffed by individuals who reside and work in the spill area and who were conducting similar work prior to the EVOS. It would appear contrary to the intent guidelines established by the Trustee Council and PAG to fund a government agency at the exclusion of established and professional local expertise. If this project is delegated to an agency (as in 1993), there will be no opportunity for this research to be conducted by private entities.

NGOS is maintaining ongoing killer whale studies in Prince William Sound in 1993. A biopsy sampling for killer whales has recently been initiated. Genetic analysis of these tissues will help identify populations of killer whales. It will be accompanied by analysis to determine levels of environmental contaminants in the whales.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Researchers will coordinate efforts with hydroacoustic surveys conducted under the Sound Ecosystem Assessment Plan (SEA) and the Prince William Sound Science Center. (NGOS operates with a memorandum of understanding with the PWSSC). Data necessary for interpretation of the proposed "Effects of Killer Whale Predation on Recovery Rates of Injured Resources" (NMML/NMFS) or other EVOS projects will be provided to the appropriate agencies.

FY 95 BUDGET (\$K)

Personnel	46.6
Travel	4.0
Contractual	25.2
Commodities	11.0
Equipment	0.0
Indirect Costs	18.1
Subtotal	104.9
Gen. Admin.	8.8
Total	113.7

Predation by Killer Whales in Prince William Sound: Feeding Behavior and Distributions of Predators and Prey

Project Number:	95014
Restoration Category:	Research (new)
Proposed By:	North Gulf Oceanic Society and Prince William Sound Science Center
Lead Trustee Agency:	NOAA
Cost FY 95:	\$177,600
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Killer whale and harbor seal

INTRODUCTION

The classic view of predator-prey relationships is that prey populations are limited through losses to predation while predator populations are limited by restricted numbers of available prey. However, this view has often been unsatisfactory because apex predators in any system are usually diet generalists. That is, the composition of their diet will change with prey availability. Decline of a common prey may result in prey-switching, rather than in a population-level decline in apex predator numbers. The consequences of prey switching are that predation rates on one prey species can vary independently from the population size of both that prey and the predator.

Prey switching allows predator populations to remain high, even when some prey species decline. Non-lethal effects of predation increase the costs of risky activities (such as foraging) for prey species. Prey-switching has already been recognized as a possible factor important in the recovery of pink salmon (juvenile pollack possibly switch from zooplankton to salmon fry when zooplankton abundance is low). Now consider that two of the most visible, index species of apex predators affected by EVOS, bald eagles and killer whales, are both listed as "Recovering", while important food sources for these species are "Not recovering" (e.g. pink salmon for eagles, salmon and harbor seals for killer whales). In addition, according to researchers at recent EVOS Trustee-sponsored workshops, losses to these predators may be

contributing to declines or lack of recovery in harbor seals, kittiwakes, and sea otters.

Food availability is considered the probable cause of failure to recover from oil spill injury for some populations, with predation pressure considered as an alternative hypothesis. However, predation pressure is related to food availability, because predators respond to changes in their prey populations by prey switching, and because foraging and other risky activities become more costly when predation risk is high. In part because population sizes of predators appear to be recovering from EVOS-related mortality, little attention has been given at workshops to discussion of predator diet or its impact on other resources.

Some additional work is needed to more completely understand the role of predation by killer whales in Prince William Sound. Investigations into the food web dynamics of killer whales have been proposed using stable isotope and fatty acid analysis. Additionally, historical data on killer whale distributions, and feeding behavior are available. These data should be analyzed in conjunction with continued field observations in Prince William Sound to determine to what extent killer whale diet or habitat use has changed. Changes that are correlated with the distribution of prey indicate that prey-switching has occurred. This analysis should be coordinated with a feeding behavior/habitat use model of predation rates in order to estimate the impact of whales on their primary prey populations.

NEED FOR THE PROJECT

This proposal is focused on killer whale predation in Prince William Sound. The killer whale was injured by EVOS and is currently listed as recovering. However, a number of staple prey species of killer whales are listed as injured and not recovering. These include harbor seals, pink salmon, and Pacific herring. At least for harbor seals, predation by killer whales is considered an important alternative to the food limitation hypothesis as an explanation for continued lack of population growth. The unrecovered status of these species may alter whale feeding patterns and behaviors. Further, the recovery of these species may be impacted by predation by whales.

PROJECT DESIGN

A. Objectives

This project addresses the role of killer whale predation in Prince William Sound, and will accomplish five objectives:

1. Analyze historical data on feeding, habitat use and distribution of killer whales.
2. Continue field studies to photoidentify and record distribution and feeding behavior of killer whales in PWS. Pre-spill patterns of behavior documented in (1) will be compared to current behavior to evaluate prey-switching or other changes in whale behavior.
3. Determine if residents and transients killer whale pods using PWS are distinct genetically, and continue estimation of feeding differences between the two types.
4. Expand sampling of killer whale distributions into late fall and winter to determine year-round residency of whales in the Sound. This will be accomplished through remote, acoustical sampling in southwestern PWS.
5. Develop trophic models based on (1-3) to evaluate the flexibility of whale diets and to estimate the impact whales have on their prey populations in PWS. This objective will utilize information from a number of EVOS studies (acoustic sampling of pink salmon and herring, forage fish distributions, harbor seal distribution and habitat use, killer whale food-web relationships, killer whale genetic studies) to provide the best possible numerical estimates of predation rates.

B. Methods

Analyze historical data on feeding, habitat use and distribution of killer whales using GIS. Documentation of historical whale behavior is needed to establish trends related to the changing availability of prey in their environment. Private and public data have been collected by this group of researchers on killer whales since 1983. Locations of all sightings, behavior, and information on prey types recorded during each siting will be entered into a geographic information system. The extent and geographic distribution of sampling effort will also be reconstructed. Feeding data from stomach contents, scales from fish attacked by the whales, and marine mammal tissue collected following kills is also available. Using this database, historical movements and behaviors of whales will be analyzed for evidence of changes in diet or area-use patterns. Critical area will be identified and feeding behaviors will be related to the distributions of prey (data on prey distribution is being collected under SEA and other studies).

Continue field studies to identify and record distribution and feeding behavior of killer whales in PWS. Detailed photographic records of sightings provide the continuity necessary for this long-term study. This segment of the proposal relies on the monitoring of the killer whale population injured in EVOS. In addition, further data on movements and feeding behavior is needed to document dietary changes (if any) and to estimate predation rates on harbor seals, salmon, and other species. Behavioral data will be taken at each encounter while researchers are with the whales. Where possible, samples of prey remains (e.g. fish scales, tissue from marine mammals) will be collected as the whales feed. This technique has been used successfully in the past. However, it has not always been possible to know what whales are feeding on. By running this study in the same area and at the same time as the SEA program, detailed observations on the general distribution and composition of fish schools will allow

greater certainty in identifying whale prey. A concurrent study examining isotope ratios and fatty acid composition may provide complementary data on gross diet composition.

Assess genetic differences between transient and resident-type pods using Prince William Sound. Behavioral observations in the Sound and limited genetic work in other areas suggest that at least two populations of killer whales (resident and transient) exist sympatrically in the Gulf of Alaska, and use Prince William Sound. Whales of both types appear to have been lost since the EVOS (from AB pod and the AT1 group, respectively). However, while the AB pod appears to be recovering numerically, the AT1 group is not. To the extent that the two killer whale types are genetically and behaviorally separate, the AT1 group may represent a distinct, non-recovering population. Further, there is evidence, that at least seasonally, the AT1 group consumes primarily marine mammals while resident whales (AB pod and others) consume primarily fish in the Sound. Thus, to adequately understand the impact that whale predation has on marine mammal populations in Prince William Sound, it is important that the level of genetic separation and differences in food habits be established for these potentially distinct populations.

Expand historical sampling into late fall and winter to determine year-round residency of whales in the Sound. It is currently not known how many whales stay in PWS into the winter, nor for how long. This is due to sampling limitations from winter weather and low light conditions that limit photography. However, this data is necessary in order to fully understand the impact whales may be having on their prey. We will use a hydrophone system to monitor killer whale movements year round. Each resident pod of killer whales has a unique dialect of vocalizations, allowing individual pod recognition by voice-print. Two hydrophone systems will be placed in the southwestern Sound. When whales are in acoustic range, a voice-activated system records their vocalizations. The system can be monitored by VHF radio from a nearby fish hatchery. Recordings will be used to determine the duration of residency for specific pods during all months of the year.

Develop trophic models based on (1-3) to evaluate the flexibility of whale diets and to estimate the impact whales have on their prey populations in PWS. Using data from this study, in conjunction with fish distributions from SEA and forage fish studies, and isotope/fatty acid results from the proposed NMFS studies, we will model predation rates of whales in PWS. The model will link whale behavior (foraging, habitat use) with predation rates on their primary food species (suspected to be harbor seals and salmon). As apex predators, whales are generally flexible in their diet (although there is some evidence that this is not the case with killer whales). We will model the effects on different prey of prey-switching by whales, to evaluate how changes in one prey populations may be linked to the availability of alternative prey.

C. Schedule

Input of historical data into the PWSSC GIS system will begin in November 1994. Fieldwork will coincide with the "Killer Whale Monitoring" program. The final report for year one will be submitted by April 1996. A simplified model will be constructed by the end of year one. A more detailed model will be completed by year two, April 1997.

D. Technical Support

Data input, computer and GIS support will be provided by the Prince William Sound Science Center. Field equipment and support will be provided by the North Gulf Oceanic Society.

E. Location

Field work will be centered in western Prince William Sound, Alaska.

PROJECT IMPLEMENTATION

The project should be implemented as a combined effort of two spill area non-profit groups, the NGOS and PWSSC. NGOS owns or leases all equipment needed to complete the field operations in this project. NGOS will provide the historical feeding data necessary for the analysis and modeling. NGOS is currently collecting biopsy samples from killer whales for the initial genetic analysis. The PWSSC has the GIS system in place and the modeling and computer capabilities necessary to complete the project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Research efforts in the field will be tightly coordinated with the SEA plan surveys. This research will be coordinated with the SEA research program, and will utilize results of SEA modeling. This project also integrates with harbor seal, and forage fish studies. Data analysis will be coordinated with the proposed studies under the Marine Mammal Ecosystem group.

FY 95 BUDGET (\$K)

Personnel	97.6
Travel	5.4
Contractual	14.0
Commodities	6.8
Equipment	5.5
Indirect Costs	32.7
Subtotal	162.0
Gen. Admin.	15.6
Total	177.6

Partitioning of Primary Production Between Pelagic and Benthic Communities

Project Number:	95018
Restoration Category:	Research (new)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cooperating Agencies:	NOAA
Cost FY 95:	\$219,200
Cost FY 96:	\$152,200
Total Cost:	\$371,400
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

Particulate organic carbon (POC) derived from phytoplankton is the primary source of food and energy for marine organisms. Consequently, the dynamics of primary production and the subsequent fate (e.g. horizontal advection, consumption, flux, accumulation, mineralization) of the generated POC are one of major importance to a holistic study of any marine ecosystem investigations. This is particularly relevant to the SEA (Sound Ecosystem Assessment) hypothesis that has been developed for Prince William Sound. The hypothesis essentially states that the ecological state of Prince William Sound is closely linked to the oceanographic forcing of circulation in the Sound which alternates between years of strong through-flow river-like conditions, and relatively stagnant, lake-like conditions. The changes are controlled by the extent of ingress of Gulf of Alaska waters into the sound. One of the suggested implications of the hypothesis is that the rate of primary production in Prince William Sound controls the standing crop of primary consumers (e.g. zooplankton) and associated higher trophic organisms (e.g. salmon, herring, bottom fish species). For the benthos, the flux of phytodetritus within the water column is the linking factor to primary production. For high standing crops of zooplankton it is critical that a sustained supply of phytoplankton is available. In contrast, high flux of POC to the bottom would be vital to support a high abundance of benthic animals. It is conceivable that in areas of high primary production, the concentrations of zooplankton may not correspondingly be high because of loss of the phytodetritus and phytoplankton from the

generating euphotic zone via horizontal advection and/or rapid sinking. However, the strong relationship between primary production and particle flux out of the euphotic zone has been amply demonstrated in numerous studies). The extent of correlation between the two would, of course, depend upon the grazing rates and hydrodynamics of water flow. Thus, it is imperative that investigations relating to the partitioning of particulate organic carbon (POC) within the water column be an integral part of the SEA study.

In Prince William Sound there is no regional data base available on the flux of POC either to the bottom or within the euphotic zone. However, extensive data are available, spanning over several years (1979-1991, including pre- and post *Exxon Valdez* spill years), on the concentrations and accumulation rates of organic carbon, nitrogen, C/N ratios and stable isotopes of organic carbon in sediments from widely-located stations in Prince William Sound. The only data published on the POC flux is that locally for Port Valdez. In Port Valdez there is apparently a close link between the yearly concentrations of benthos and zooplankton with implied coupling with the POC flux and primary consumers. Given the extensive data base that we have on organic carbon contents as well as accumulation rates of sediments, studies to determine water column POC fluxes would help to complete the carbon budget, and define food web linkages within the overall ecosystem of Prince William Sound. Our proposed investigation will include the deployment of a mooring with two sediment traps at a selected location in central Prince William Sound, to obtain time-series (monthly) and sequential samples of mass particle and POC flux. This project will be closely integrated with the proposed studies by Drs. McRoy and Eslinger on nutrient dynamics and primary production and will ultimately have strong bearing on the investigations on zooplankton led by Dr. Cooney under the SEA project.

PROJECT DESCRIPTION

As mentioned earlier, our proposed investigation on particle and POC flux will have strong relevance to understanding the role of carbon flux partitioning in the supply of food to pelagic primary consumers and to the benthic system. The data obtained under this investigation will be shared with Drs. McRoy, Eslinger and Cooney in attempting to test the SEA hypothesis, and with other investigators working in the sound area.

In attempting to address damage assessment/restoration of the Prince William Sound ecosystem subsequent to the *Exxon Valdez* oil spill, it is critical first to have a quantitative understanding of the natural forces and processes which drive the ecosystem of the sound. This concern has been identified by the EVOS Trustee Council as a high priority research topic. Without the above baseline it would be difficult, except in obvious high direct impact situation, to make any value judgement as to what the damages and restorations may have occurred consequent to the spill. Therefore, the investigations proposed under the SEA hypothesis, of which our studies will be a complementary component, will serve an useful purpose in assessing damage and designing steps for restoration. Our study will link the individual yet related investigations that are being proposed by Drs. McRoy and Eslinger on primary production and by Dr. Cooney on zooplankton dynamics. Additionally, we will examine our data on time-series changes in the

carbon flux within the water column in context of the investigation on hydrodynamics that are being proposed by Dr. Salmon. In fact, all the above studies have been conceived, with mutual understanding, from the standpoint of a multidisciplinary approach to ecosystem analysis. Perhaps the results of our investigations and that of the SEA, could be extended to nearshore regions which are now being impacted by crude reworked from the beaches, to help assess the causes of environmental changes.

A. Objectives

1. To estimate the time-series variations in the natural vertical fluxes of particulate organic carbon (POC) in Prince William Sound, and the partitioning of the flux between faecal pellets and loss of intact diatom cells via sinking.
2. To establish the relationship between our data on time-series changes in the POC fluxes and the timing and biomass of phytoplankton cycles that Drs. McRoy and Eslinger have proposed to measure and the time-series changes in hydrodynamics that would be recorded at the C-Lab and other buoy stations in Prince William Sound. The overall objective of this task would be to test the SEA hypothesis.
3. To integrate the water column POC flux data with the sediment POC accumulation rate estimates that are available from our previous work in the sound. This will assist in assessing the demand and consumption of POC by benthos and the rates of organic matter remineralization and burial.

B. Methods

To successfully meet the task objectives of this proposal the flux measurements must be closely integrated with the studies that have been proposed by other investigators of the SEA project, especially with the phytoplankton and zooplankton studies. The flux measurements will be carried out by taking time-series (monthly) samples of POC flux using two sets of sediment traps. The trap design will be after the prototype model PARFLUX Mk6, which is one of the most sophisticated types in use today. This trap has the capability of collecting time-series, sequential flux of settling particles with flexible intervals without hiatus for 18 months. The sampler has a 0.52m intake vent which opens into individual receptacles that rotate into position sequentially at preset time intervals programmed by a microprocessor (refer to Asper, 1988 for further details on the trap design and operation).

We propose to deploy two sediment traps, effective November 1994, at different depths on a mooring that has an array of instruments deployed by the SEA investigators and/or Dr. D. Salmon. The flux measurements will be carried out for two years, which will allow assessment of the changes in fluxes between years and several seasonal cycles that might have significant shifts in the rate of primary production. Care will be taken to ensure minimum interference by other instruments in the collection of vertical flux of settling particles. One of the traps will be emplaced just below the thermocline and the other near the bottom of the sound at water depth where resuspension of particles is assumed to be absent. The upper trap samples will provide

estimates of the time-series fluxes of POC out of the euphotic zone and thus the food supply available to the primary consumers. The lower trap samples will provide estimates of the time-series fluxes of POC to the sound floor. Each of the sample receptacles in the trap will be filled with water having a density higher than the surrounding water to help retain the trapped particles in the receptacle. This high density water will be poisoned with HgCl to preserve the samples from bacterial degradation. The exact time of deployment and retrieval of the traps will be noted.

Each of the samples collected in the field will be transferred into prewashed glass bottles and stored frozen (-20.0 C) until ready for analysis. The determination of the total particulate content, POC, N and C/N will be after the methods outlined in Feely et al. (1991), Knauer (1991) and Bodungen et al. (1991). Briefly, each of the samples will be filtered through GF/F glass filter membrane which has been prewashed with deionized water, precombusted at 500° C for 4 hrs and preweighed. Following filtration the samples will be rinsed in deionized water to free the samples of salts. The dry weight of particulates retained on the membrane divided by the days of deployment and the trap mouth cross-sectional area will provide the total flux rate of particulates. Prior to analysis of the POC the samples will be exposed to vapors of a weak acid to remove carbonates. The concentrations of POC and N, which will be analyzed in an automatic CHN analyzer, will be reported on a dry weight basis. The sediment traps will be calibrated against known rates of Pb-210 based sediment accumulation rates for the study area.

C. Schedule

The start date for this project will be October 1, 1994 and the end date will be September 30, 1996. It is intended to collect flux samples for every month starting from November 1994, so that we will have samples corresponding to various seasons and cycles of primary productivity. During the above duration it is assumed that productivity, zooplankton and hydrographic data will be simultaneously collected by the SEA project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

As mentioned earlier, this project will closely interact with other studies, especially those that are being proposed under the SEA project and by Dr. D. Salmon on water circulation. Sample collection will be in conjunction with the SEA project and the deployment of the sediment traps will be integrated with the mooring to be set by the SEA project and/or by Dr. Salmon. The POC flux data will be integrated and examined in context of the data that will be obtained by the investigators addressing the phytoplankton, zooplankton, and water mass dynamics. We will fully cooperate and be involved with the modelers who will be testing the SEA hypothesis and other ecosystem modelers working in Prince William Sound. The proposed study has been discussed with the investigators of the SEA project and with Dr. Salmon, all of whom have agreed to collaborate. The budget reflects support for the effort involved by Dr. Salmon in the mooring operations. We will be needing four days of ship time in a year for the deployment and retrieval of the sediment traps. It is anticipated that the ship time will be provided by the Alaska Department of Fish and Game as an overall effort in the deployment of moorings

concerned with the SEA project and/or Dr. Salmon's hydrographic investigations. However, sufficient funds have been budgeted in our proposal to share part of the cost of the trap deployment. The cost of the acoustic release (10K) as stated in the subcontract proposal will be refunded to the EVOS Trustee Council in case the primary responsibility of the installation, deployment and recovery of the moorings to which our sediment traps will be integrated, is entrusted to investigators of the SEA project.

FY 95 BUDGET (\$K)

Personnel	7.2
Travel	0.0
Contractual	197.1
Commodities	0.0
Equipment	0.0
Subtotal	204.3
Gen. Admin.	14.9
Total	219.2

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Distribution of Forage Fish as Indicated by Puffin Diet Sampling

Project Number:	95019
Restoration Category:	Research (new)
Proposed By:	National Biological Survey
Lead Trustee Agency:	DOI
Cost FY 95:	\$271,300 (includes data analysis and report writing costs.)
Cost FY 96:	\$218,300 (includes data analysis and report writing costs)
Total Cost:	Unknown
Duration:	3 years (useful results can be obtained in 1 year; 3-year project is recommended to assess interannual variation in composition of forage fish stocks)
Geographic Area:	Naked Island, Smith Island, Porpoise Rocks, Wooded Islands, Chiswell Islands, Barren Islands
Injured Resource/Service:	Multiple resources

INTRODUCTION

Tufted puffins are widely distributed in breeding colonies throughout the *Exxon Valdez* oil spill area. During the chick-rearing period, adults make several trips daily to the nesting burrow, carrying fresh prey to their young. By intercepting those food deliveries, it is possible to sample the nestling diet of puffins systematically and nonconsumptively. Puffins are representative of seabirds (common murre, marbled murrelets, pigeon guillemots, black-legged kittiwakes and others) that rely in summer on a common food base consisting of forage species like capelin, sand lance and smelts, and the juveniles of commercially important species such as pollock, herring, and salmon. This project will use puffin diet sampling as a means to quantify seasonal, annual, and geographic variation in the composition of the forage fish community at selected stations within the spill area. The project will complement traditional, more costly approaches involving hydroacoustics and net sampling and will also provide a reliable source of seabird prey specimens for laboratory analysis.

NEED FOR THE PROJECT

Three species of marine birds (common murre, marbled murrelet, and pigeon guillemot) and one pinniped (harbor seal) were injured by the *Exxon Valdez* oil spill and are not recovering. An additional species (black-legged kittiwake) showed early effects on reproduction (comparing oiled and unoled areas) and has experienced widespread breeding failure throughout Prince William Sound in the last two years. The summer diets of these and other members of the pelagic community of vertebrate predators (birds, mammals, and fish) are known to overlap. One hypothesis to explain the failure of recovery of injured species is that adverse changes are occurring in the quantity or quality of these species' prey. To test that hypothesis, it is necessary to quantify the status and trends of prey populations, particularly the forage fish that comprise an important part of the summer diet. Few data are available on the distribution and abundance of forage fish, because most species are not commercially harvested, and traditional methods of fishery science tend to be difficult and expensive. In the Gulf of Alaska, tufted puffins have proved to be excellent samplers of the forage fish community, providing annual indices of the distribution and relative abundances of keystone species such as capelin, sandlance, pollock, myctophids, and squids. Conducted over a span of years, this approach offers a cost-effective means of monitoring key components of the pelagic ecosystem and testing the hypothesis that recovery of marine birds and mammals is influenced by changes in the composition of marine fish stocks.

Seabirds in general, and puffins in particular, may constitute an important mortality factor on the early life stages of commercially important species. In the Gulf of Alaska, Hatch and Sanger calculated that tufted puffins took 11 billion pollock from mid July to mid September, roughly one-tenth of the first-year juveniles available just prior to chick-rearing and ten times the number of fish surviving to the following March. On the Barren Islands in 1993, puffins frequently delivered juvenile sockeye salmon, although the smolt were too large to be readily ingested by the chicks, and many went to waste.

Whether seabird predation proves to be a significant source of mortality or not, previous results suggest that diet sampling can provide an early indication of year-class strength in some species. For instance, the proportion of pollock in tufted puffin diets at the Semidi Islands (western Gulf of Alaska) was strongly correlated over three years with independent measures of year-class strength obtained in fishery investigations. A similar outcome might be obtained for sockeye salmon at the Barren Islands or pink salmon in Hinchinbrook Entrance to Prince William Sound, where an out-migration of juveniles in late summer and fall would encounter the sizeable puffin colonies on Porpoise Rocks and the Wooded Islands.

Because puffins deliver whole, undamaged prey to their chicks, this project can serve as a ready source of specimens for determination of prey quality (composition and energy density), population structure (age-sex ratios, genetic stock identification), and trophic studies (fish stomach contents, stable isotope ratios and/or lipid analysis). Puffin samples have also been used to estimate daily growth increments of juvenile sandlance and pollock.

PROJECT DESIGN**A. Objectives**

1. Annually assess the species composition of the forage fish community near selected colonies of seabirds in the northern portion of the *Exxon Valdez* oil spill area.
2. Cross check the species composition of forage fish as determined by puffin diet sampling and hydroacoustic/net sampling techniques.
3. Assess the timing and magnitude of puffin predation on commercially important prey species including Pacific herring, pink salmon, and sockeye salmon.
4. Furnish whole prey specimens on demand for complementary studies of prey energetics, food web relationships, and fish population characteristics.

B. Methods

Puffin diet samples are collected most efficiently by placing wire screens over the entrances to burrows. Unable to enter, returning adults frequently drop their food loads on or near the screens, which are removed when the samples are retrieved after 1-3 h. Samples are washed, bagged and preserved for later analysis in the laboratory. Any temporal sampling design that may be desired can be implemented, but for maximizing the quantity of food obtained, morning hours tend to be most productive because puffins generally make a food delivery soon after first daylight.

One issue raised by this sampling approach is whether puffins take different types of prey in proportion to their relative abundances in the water column. Therefore, a desirable element of the field work during the first year of this project would be a comparison of the results from puffin diet sampling with simultaneous deployment of hydroacoustics and net sampling offshore at one or more colonies. The offshore work is not budgeted for in this proposal, but it is anticipated that the coordinated study would be achieved through cooperation with other projects (forage fish assessment or SEA plan) proposed for fiscal year 1995.

Puffin productivity (chicks per burrow surviving at a late stage of the breeding season) and breeding chronology (estimated from chick wing lengths) will be monitored at little or no additional cost in each of the study colonies.

C. Schedule**Fiscal Year 1995**

Nov-June	Establish contracts, recruit personnel, safety training, boat and collection equipment preparation.
July-Aug	Field collection of puffin diet samples at six sites in Prince William Sound and northern Gulf of Alaska; coordinated investigation of sampling methods at Porpoise Rocks.
Sept	Laboratory analysis of food samples.

Fiscal Year 1996

Oct-Dec	Complete laboratory analysis; data analysis and report writing.
Jan	Draft annual report.
March	Final annual report.

D. Technical Support

Prey samples may be identified and measured under contract to the University of Alaska or a private consultant.

E. Location

The Porpoise Rocks colony in Hinchinbrook Entrance is strategically located relative to juvenile salmon migration. It is probably also the best location for a comparative study of sampling techniques. Additional colonies in Prince William Sound would include Naked Island, Smith Island, and the Wooded Islands. Outside the Sound, but in the path of the oil spill, colonies of first choice include the Chiswell Islands and Barren Islands. There is some question whether puffin habitat on the Chiswells is sufficiently accessible; if not, at least one alternative site would be worked along the Kenai Peninsula or in the Kodiak Island area.

PROJECT IMPLEMENTATION

This project will be implemented by the Alaska Science Center, National Biological Survey. Center personnel developed the field techniques proposed for puffin diet sampling and have successfully applied the methods at more than 20 puffin colonies in the Gulf of Alaska since 1985.

COORDINATION OF INTEGRATED RESEARCH EFFORT

As previously noted, coordination with offshore operations that sample forage fish by traditional methods is a highly recommended component of this project. The project will contribute to and draw upon SEA investigations of juvenile salmon and herring, and will use information on physical oceanography generated by other EVOS funded studies in the interpretation of seasonal, annual, and geographic variation in forage fish communities.

FY 95 BUDGET (\$K)

Personnel	138.1
Travel	20.6
Contractual	21.6
Commodities	10.8
Equipment	58.0
Subtotal	249.1
Gen. Admin.	22.2
Total	271.3

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Seasonal Movements and Pelagic Habitat Use by Common Murres from the Barren Islands

Project Number:	95021
Restoration Category:	Research (new)
Proposed By:	National Biological Survey
Lead Trustee Agency:	DOI
Cost FY 95:	\$230,900 (includes data analysis and report writing costs)
Cost FY 96:	\$221,100 (includes data analysis and report writing costs)
Total Cost:	\$452,000
Duration:	2 years (useful results can be obtained in 1 year; 2-year project is recommended to assess interannual variation in the foraging behavior of common murres)
Geographic Area:	Barren Islands
Injured Resource/Service:	Common murre

INTRODUCTION

Small (30 g) satellite transmitters have recently become available for use in wildlife telemetry. These implantable devices are proven effective when deployed on birds in the size range of common murres, i.e., about 1 kg. In this project, satellite transmitters will be surgically implanted in a sample of murres from the Barren Islands to determine both the summer feeding areas and wintering areas of birds from this heavily impacted colony. This information will be vital for designing and optimizing an investigation of food availability to murres and for testing the hypothesis that food limitation is constraining the recovery of the Barren Islands population following the *Exxon Valdez* oil spill.

As diving birds, murres do not access the entire water column uniformly, but concentrate their foraging activity in depth ranges dictated by the distribution of their preferred foods and limitations imposed by their own diving physiology. This additional information is needed to address the question of food limitation on murre productivity and recovery. Externally mounted depth recorders will be used to determine the average time-at-depth for common murres foraging in the vicinity of the Barren Islands.

NEED FOR THE PROJECT

Common murres were among the vertebrate species most seriously injured by the *Exxon Valdez* oil spill. About 75% of the 35,000 bird carcasses recovered during and shortly after the event were murres, and estimates of murre losses were in excess of 100,000 individuals. After the oil spill, fewer breeding murres were found at the Barren Islands compared to historical data, and annual censuses have not detected any recovery in numbers. Also, based on data from Nord Island, production of chicks was almost zero in both 1989 and 1990, and still low in 1991 and 1992 compared to colonies outside the spill zone.

One hypothesis to explain the failure of recovery in common murres is that food availability is limiting the ability of birds to breed successfully or to survive in sufficient numbers during the nonbreeding season. An evaluation of that hypothesis requires that we identify the principal feeding areas of murres in both seasons and design appropriate oceanographic studies to assess the factors affecting food availability. Telemetry offers a more cost-effective approach for determining foraging patterns and habitat use than is possible using traditional survey methods.

In many populations of seabirds, the majority of natural mortality occurs during the winter months. Problems with the food supply on the wintering grounds may constrain the recovery of Barren Islands murres even if productivity improves. Probably there is another critical period in fall, when recently fledged young make the transition to self-feeding. However, the existence or location of possible "nursery areas" is all but unknown for this and other populations of seabirds.

Through the combined use of satellite transmitters and time-depth recorders, this project will provide a three-dimensional view of murre foraging patterns around the Barren Islands in summer. Additionally, transmitters deployed in fall and tracked through the winter months will reveal the primary wintering areas used by this population. It may also be possible to locate key foraging areas of juvenile murres by deploying transmitters on breeding males late in the season. Flightless murre chicks are led to sea by their male parents, who continue to provide parental care for several weeks as the young learn gradually to feed themselves.

PROJECT DESIGN

A. Objectives

1. Determine the foraging range and primary feeding areas of common murres from the Barren Islands, including assessment of individual and temporal variation.

2. Locate important nursery and/or wintering areas of common murres from the Barren Islands and determine the timing of use of those critical habitats.
3. Obtain average time-at-depth profiles for a sample of foraging murres from the Barren Islands.

B. Methods

Murres will be captured with poles and nooses during incubation and chick-rearing periods in the Lighthouse Rock portion of the colony on East Amatuli Island. Transmitters will be surgically implanted by a qualified veterinarian. The ARGOS Data Collection and Location System will be used to track the movements of instrumented birds. Transmitters will be programmed to emit signals on one of two duty cycles: (1) continuous transmission, providing frequent information on locations (accurate to ≤ 1 km) over a 3-week period (expected battery life), or (2) low-interval transmissions (e.g., 6 h every 3 days) for less frequent position data over the course of an annual cycle (52 weeks). Position data will be mapped using CAMRIS (Computer Aided Mapping and Resource Information System) or other suitable GIS software.

Time-depth recorders are relatively inexpensive devices employing hypodermic syringes and photographic film to record the depth-dependent position of an light-emitting diode). The instruments are attached externally to the dorsal feathers and must be retrieved after an appropriate interval to obtain the data on diving depths. Information on the depth and duration of dives is cumulatively recorded on the film, and the exposed film is analyzed using a densitometer. Each unit is calibrated prior to deployment. LED depth recorders have been used successfully with thick-billed murres in the Canadian Arctic and on smaller alcid species in the North Pacific.

C. Schedule

Fiscal Year 1995

Nov-June	Establish contracts, recruit personnel, procure satellite transmitters and LED depth recorders.
July-Aug	Field operations at East Amatuli Island, begin data acquisition via ARGOS.
Sept	Continue ARGOS data acquisition, densitometer readings and interpretation of LED depth recorder films.

Fiscal Year 1996

Oct-Dec	Continue ARGOS data acquisition, data analysis and report preparation.
Jan	Draft annual report.
March	Final annual report.

D. Technical Support

The manufacture, calibration, and optical density measurements of LED depth recorders will be contracted to a qualified specialist. This project also requires the services of an experienced veterinarian and access to the ARGOS data-logging and distribution system, both of which are available in the Alaska Science Center of the National Biological Survey.

E. Location

These studies will be carried out in the colony at the north end of East Amatuli Island, the more accessible of two colonies of common murres in the Barren Islands.

PROJECT IMPLEMENTATION

The project will be implemented by the Alaska Science Center, National Biological Survey. In addition to the in-house technical support mentioned above, Center personnel have unique experience with implantable satellite transmitters for recording the movements of birds at sea. The Principal Investigator for this project has scheduled a pilot study of transmitter implants and satellite tracking of common murres in the Gulf of Alaska during July 1994.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Work on East Amatuli Island will be coordinated with the monitoring study of common murres proposed for that site to facilitate the telemetry study and avoid any conflicts between the two. Results of this study should be used in planning future investigations of the food limitation hypothesis as it pertains to common murres.

FY 95 BUDGET (\$K)

Personnel	107.3
Travel	9.6
Contractual	10.5
Commodities	22.9
Equipment	63.8
Subtotal	214.1
Gen. Admin.	16.8
Total	230.9

Food Web Relationships of Pelagic Species Exhibiting Long-Term Decline

Project Number:	95023
Restoration Category:	Research (new)
Proposed By:	Alaska Natural Heritage Program, UAA
Lead Trustee Agency:	DOI
Cost FY 95:	\$133,200
Cost FY 96:	\$170,000
Total Cost:	Unknown
Duration:	3 years (useful results can be obtained in one year; 3-year project is recommended to assess the effects of interannual variation on the diets of the species in the study and to develop a model of trophic interactions of Prince William Sound)
Geographic Area:	Prince William Sound and adjoining portions of the oil spill area
Injured Resource/Service:	Common murre, marbled murrelet, pigeon guillemot

INTRODUCTION

This project will look at the food webs of Prince William Sound, focusing on diets of seabirds damaged by the *Exxon Valdez* oil spill, the common murre, marbled murrelet, pigeon guillemot and several other seabirds selected for their utility as environmental samplers. Diets will be examined in relation to those of Pacific herring and other forage fish and to the predatory fish such as Walleye pollock that might interact with either the birds, as competitors, or the forage fish, as competitors or predators.

We will use historical data from published studies and from stable-isotope analysis of existing specimens if possible to compare with data gathered during through subprojects of this one, from other EVOS studies, and from recovery of carcasses of animals found dead.

These data will be used to develop simple carbon-flow models to examine the relative importance of different pathways between decades and between areas and to compare these pathways with what is known of changes in the populations of EVOS-injured species and other ecosystem indicators.

NEED FOR THE PROJECT

Marine ecosystems can fluctuate and, in the North Pacific, they vary at a wide variety of scales that affect seabirds and other marine organisms. This variability can enhance, retard or obscure the effects of single events such as the spill of the *Exxon Valdez* in Prince William Sound, Alaska. For example, resources that were damaged by the oil spill may not have recovered because of climatic variability that rendered the environment less favorable or there may be lingering effects of the spill that might be open to amelioration. Reductions in some species might trigger increases in their prey that then in turn compete with third species, preventing their recovery.

We can not address these or other possibilities concerning recovery or manage Prince William Sound as an ecosystem unless we understand the existing trophic networks that operate within the ecosystem. While understanding an entire trophic structure of the Sound is an open-ended project that would require years, if not decades, we can test hypotheses and develop models centering on injured resources that should help give us a working knowledge of how the trophic networks function, sufficient to allow us to assist the restoration process or, in the very worst case, at least to understand the magnitude of the task.

PROJECT DESIGN

The project will run for three years, to test interannual variability. The first year will involve collection of historical data and synthesis of data from ongoing studies. The second year will continue data collection and the initial modelling exercise. The third year will see refinement of the model and testing of its predictions through limited field work.

The project will have two sampling components and analysis methods to provide the data for model construction. For examination of trophic interactions at short-terms over small scales, we will undertake analysis of diet through classical diet analysis techniques. We will collect diets through direct field work by research collaborators and ourselves. To get a larger-scale picture of trophic interactions, we will use our own collections and public salvage of specimens for stable-isotope analysis of the trophic levels of constituent species.

We will then use either carbon-flow, biomass, trophic level models), or spatial/oceanographic approaches to modelling the food web.

A. Objectives

1. Define the food web relationships of key species in the pelagic ecosystem of Prince William Sound and adjacent portions of the spill zone.
2. Assess seasonal, annual, decadal and regional variation in the diets of injured species of marine birds (common murre, marbled murrelet and pigeon guillemot) and selected indicator species including tufted puffins and black-legged kittiwakes that may serve as monitors of the ecosystem.

3. Test the null hypotheses that 1) no changes in diet occurred cohesively among several species between decades; and that 2) interannual variability in diet does not occur at a scale that might obscure interdecadal change. If the null hypotheses can be rejected, we will test the overall project hypothesis that Prince William Sound has shifted from a pelagic to a demersal ecosystem in terms of fish production.
4. Synthesize information on trophic dynamics in Prince William Sound and the northern Gulf of Alaska and derive a model or models of species interactions that predict the relative importance of competition and predation on the recovery of injured species.

B. Methods

1. The project will coordinate with other studies in the marine bird program. It will use diet data on food habits collected using nonconsumptive techniques in other projects. We will undertake fieldwork to fill in any gaps in coverage. We will provide technical assistance on stomach pumping to increase the use of non-lethal sampling and will coordinate efforts to ensure complete coverage.
2. The project will encourage widespread efforts by the public and governmental agencies to collect carcasses of birds found dead (washed up, dead in fishery operations, etc).
3. The project will undertake stable isotope analysis using material from dead birds recovered as above, from stomach contents derived from nonlethal sampling of birds, and from forage and predatory fish from fishery operations and from the SEA Plan.
4. Diet contents will be assigned to broad trophic levels or guilds and analyzed for spatial and temporal variation and for congruence in diet and diet change between species. Carbon flow models for different areas and decades will be constructed. We will then examine known or inferred changes in populations of the constituent species (temporal change) and relative abundance of species (geographic variation) that might represent transitions between the different carbon models.
5. We can test spatial predictions of models by sampling in new areas in the third year. Temporal predictions may be more difficult to test unless significant climatic or other change can be detected independently.

C. Schedule**Fiscal Year 1**

Oct-Apr	Establish contracts, set up public involvement process for collecting of specimens training for field sampling, preparation for field work.
Feb-Mar	Undertake winter sampling.
Feb	Begin public collection process and analyze specimens as they become available.
June-Aug	Field work in Prince William Sound and adjacent spill areas.
Sept	Analyze data from collaborators as they become available. Initial report completed.

Fiscal Year 2

Oct-Dec	Continue analysis of specimens from public salvage efforts and from own field work and collate data from collaborators. Initial scoping effort to determine most effective models relative to available data.
Jan	Prepare report on first field season; town meetings on results in Anchorage, Valdez and Seward. Begin modelling exercise.
Feb-Mar	Undertake winter sampling.
May	Prepare for summer sampling.
May-Sept	Continue analysis of specimens from public salvage efforts, undertake own field work and collate data from collaborators.
June-Aug	Field work in Prince William Sound and adjacent spill areas.
Sept	Second-year report completed.

Fiscal Year 3

Oct-Dec	Continue analysis of specimens from public salvage efforts and from own field work and collate data from collaborators. .
Jan	Prepare report on second field season; town meetings on results in Anchorage, Valdez and Seward. Continue modelling, integrating second year's data.
Feb-Mar	Undertake winter sampling.
May-July	Limited final field work in Prince William Sound and adjacent spill areas to test model predictions or gather missing data.
July-Aug	Final analysis of data, running of final model and preparation of report.

D. Technical Support

A stable-isotope laboratory and a lipid laboratory will be involved in the project in the first year. Based on initial results, their roles will be determined for the second two years. Field work will be conducted on private vessels and collection of specimens of organisms found dead in the Prince William Sound area will require support from management and regulatory agencies (U.S. Fish and Wildlife Service, Alaska Division of Fish and Game, U.S. Coast Guard, local police) and nongovernment groups (Native Corporations, fishermen and anglers). Collection of samples will be coordinated with other EVOS-funded researchers and any others active in the area. Modelling efforts in the second and third year may require additional participants.

E. Location

Prince William Sound and adjacent portions of the spill area. Particular locations will be determined by work by cooperating scientists and by specimens contributed by the public. Our field work will be directed at filling in geographic 'gaps' in coverage in the first two years. In the third year, we will use field work to test model predictions in a previously unsampled area.

PROJECT IMPLEMENTATION

Project will be managed by the Alaska Natural Heritage Program (AKNHP), with field work and data collection by personnel from AKNHP, National Biological Survey, and other agencies. AKNHP have extensive experience coordinating projects involving multiagency efforts. AKNHP is also by mission and experience able to handle and integrate data from diverse sources, as will be required for this project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will rely heavily on coordination and cooperation with other researchers who will collect data on diets as parts of their own studies. Initial mechanisms for coordination stem from the scientific planning meeting of the Oil Spill office in April. Further coordination would be an integral part of the overall marine bird project. Also we plan to rely on provision of carcasses found by the public (fishermen, beachcombers, tourist operators) and by various state and federal agencies. This will be achieved by site visits, town meetings, use of media, and extensive communication with appropriate governmental and other agencies.

FY 95 BUDGET (\$K)

Personnel	52.0
Travel	21.0
Contractual	35.0
Commodities	10.0
Equipment	5.0
Subtotal	123.0
Gen. Admin.	10.3
Total	133.2

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Enhancement of Prince William Sound Wild Salmon Stocks

Project Number:	95024
Restoration Category:	General Restoration (new)
Proposed By:	Village of Eyak
Lead Trustee Agency:	ADFG
Cost FY 95:	\$184,000
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	10 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink salmon, subsistence, commercial fishing

INTRODUCTION

Wild stocks of pink and chum salmon in many Prince William Sound streams have been at severely depressed levels for many years despite fishery closures. Recovery of these salmon stocks was adversely affected by the oil spill either directly or when fry outmigrated through oiled areas. These wild stocks of salmon have been the basis of a subsistence way of life for the native people for thousands of years. Since these stocks are not recovering, a project to rehabilitate and restore wild pink and chum salmon is proposed.

The general consensus of opinion of the residents of Prince William Sound effected by the oil spill is that the results of all the money spent on "restoration studies" thus far proposed will be another large library and employment for experts from unaffected areas. Studies usually have a net negative effect on the subject population. When all of the money has been spent, both the area resources and access to those resources by the dependent human population will be reduced.

This proposal is designed to rehabilitate rather than study depressed populations of wild pink and chum salmon as well as the subsistence, commercial, and recreational fisheries dependent on those populations. This will be accomplished using established fish culture techniques which when properly implemented have proven successful. Existing and proposed studies will benefit from this project by their being provided with known populations of pink and chum salmon as well as access to the logistical support necessary to accomplish the project.

Local hire will supply most of the professional, technical, training and logistical services required to implement this project. This will provide employment options to some of those most severely impacted by the oil spill.

NEED FOR THE PROJECT

This project will aid in the restoration of wild pink salmon (noted by EVOS as a non-recovering biological resource), wild chum salmon, and the subsistence fishery (noted by EVOS as a lost or reduced service).

The restoration of the subsistence fishery by those most affected and the jobs created by this project will create hope for the future. This could help alleviate the increase in divorce, domestic violence, alcoholism, and other social ills caused by the cultural disruption and economic desperation due to the oil spill.

PROJECT DESIGN

A. Objectives

1. The first phase of the project will be to identify which streams in Prince William Sound have been below minimum ADFG escapement goals for three generations (two generations for chum salmon) but which have a remnant population that can be used as an egg source. Special emphasis will be placed on streams with a previous history of good production where the limiting factor is inadequate escapement. This task can be accomplished by review of existing ADFG records.
2. Phase two of the project will involve site surveys to determine its suitability for streamside incubators and netpen rearing sites.
3. Phase three will involve the installation of streamside incubators and the negotiation of agreement with existing hatchery operators for the remote incubation of salmon eggs from the candidate streams.
4. Phase four will be the actual fish culture portion including: eggtakes, egg and fry transportation, incubation, marking, and pen rearing of fry to achieve optimum survival rates.
5. The final phase will be the evaluation of the adult returns to determine if the objectives of the project are being met.

B. Methods

Depressed stocks of wild pink and chum salmon will rehabilitate in selected Prince William Sound streams by a combination of three techniques:

1. Streamside incubators will be installed where suitable conditions exist.
2. Eggs will be collected from candidate streams, incubated at an existing hatchery facility and returned to their native stream for release.
3. Pen rearing will be utilized in some instances to increase survival rates by releasing larger fry. This technique can also be used to hold early emergent fry so they can be released when zooplankton populations are conducive to maximum survival.

Eggtake, incubation, marking, fry transport, and rearing operations will be conducted using techniques that have proven successful in previous Prince William Sound fish culture programs.

C. Schedule

A detailed schedule of activities will be provided with the work plan.

D. Technical Support

With the exception of the services of the ADFG pathology and mark recovery labs most of the technical support will be provided by the proposer.

E. Location

Prince William Sound. The communities affected are Cordova, Tatitlek, Valdez, Whittier and Chenega.

PROJECT IMPLEMENTATION

This project is proposed by the native village of Eyak Tribal Council which has interest in the health of the salmon resource and the subsistence fishery it supports.

COORDINATION OF INTEGRATED RESEARCH EFFORT

It will be necessary to develop a working relationship with the Alaska Dept. of Fish and Game, U.S. Forest Service, Village of Tatitlek, Chenega Bay, and the private aquaculture operators in Prince William Sound.

FY 95 BUDGET (\$K)

Personnel	6.7
Travel	0.0
Contractual	164.8
Commodities	0.0
Equipment	0.0
Subtotal	171.5
Gen. Admin.	12.5
Total	184.0

Factors Affecting Recovery of Sea Ducks and their Prey

Project Number:	95025A
Restoration Category:	Research (new)
Proposed By:	DOI
Cost FY 95:	\$415,100
Cost FY 96:	\$307,800
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harlequin duck

INTRODUCTION

Sea ducks are an important avian component of the nearshore ecosystem of Prince William Sound, particularly in winter. During March 1972 - 1991, sea ducks constituted 36% of birds observed from Prince William Sound boat surveys. The sea duck community is composed of a diverse assemblage of species, including harlequin ducks (*Histrionicus histrionicus*), Barrow's (*Bucephala islandica*) and common (*B. clangula*) goldeneyes, white-winged (*Melanitta fusca*), surf (*M. perspicillata*), and black (*M. nigra*) scoters, oldsquaw (*Clangula hyemalis*), buffleheads (*B. albeola*), and mergansers (*Mergus* spp.).

Sea duck studies are an appropriate use of restoration funds both because sea ducks were injured by the EVOS and because they affect populations of other injured organisms on which they prey. Sea ducks reside in nearshore habitats, where continuing oil contamination is likely. Harlequin duck populations in the oiled zone of Prince William Sound were documented as injured by the EVOS; harlequins are classified as an injured resource. Some evidence of injury to scoters and goldeneyes in the oiled zone was documented by marine bird surveys. The surveys also documented extreme Sound-wide declines of scoters in the two decades preceding the spill. These species were not studied individually during the Damage Assessment process; given the reliance of sea ducks on nearshore habitats that retained oil, it is probable that such studies would have documented further injury. In addition, sea ducks prey on intertidal and shallow subtidal organisms, such as mussels. These prey organisms were classified as injured resources. It is possible that continuing predation by sea ducks is limiting recovery of these organisms.

Wintering biology and ecosystem interactions of sea ducks are poorly known. Most ecological studies of wintering sea ducks are from Europe or the Atlantic coast). While some work has been done in the Pacific with sea duck winter foraging, only two winter studies have been conducted in Alaska, neither in Prince William Sound. Most aspects of sea duck wintering biology have not been addressed. For example, it is possible that harlequin duck breeding and winter populations in Prince William Sound are comprised of the same individuals. The Restoration Strategy should include winter studies to examine the possibility that breeding harlequins are failing due to continued contamination or food shortage throughout the winter.

An intensive study of sea duck wintering ecology and ecosystem interactions would serve to elucidate factors that limit populations and may be influencing recovery of injured species and systems. This study is comprised of two related components: survival and movements, and foraging ecology of wintering sea ducks.

NEED FOR THE PROJECT

Survival and movements: Overwinter survival of sea ducks in Prince William Sound likely has important, direct effects on annual population dynamics and specific annual variation of wintering numbers in Prince William Sound. Factors that are influencing survival must be understood to identify processes limiting recovery of injured species and systems. Through incorporation of estimated survival rates into population dynamics models, sustainability of populations can be determined.

Sea duck survival is a good measure of the health and productivity of the nearshore system. Sea ducks rely on intertidal and shallow subtidal areas for foraging. Disturbances of these habitats and the invertebrate prey inhabiting them likely directly affect benthic foragers like sea ducks.

Condition and foraging ecology: The foraging ecology component will address several concerns related to restoration of sea ducks and their prey. These concerns include whether (1) trophic interactions, competition, food availability, or food quality are limiting recovery of sea ducks, (2) injured benthic invertebrates are not recovering because they are important sea duck food items, or (3) oil continues to be ingested and/or accumulated by sea ducks.

Herring eggs might be an important food for sea ducks in late winter. Spring condition has important implications for subsequent reproductive performance in many waterfowl species.

PROJECT DESIGN

A/B. Objectives and Methods

1. Identify major causes of sea duck mortality and limiting effects of winter survival for sea duck recovery.
2. Examine whether trophic interactions, competition, food availability, or food quality are limiting recovery of sea ducks.
3. Identify major sea duck prey species, so that related studies of injured benthic invertebrates can evaluate whether those species are not recovering because they are important sea duck food.

Survival and Movement

Objectives. In Prince William Sound, there are several potential sources of sea duck winter mortality including harvest, starvation or exposure, predation, disease, and exposure to contaminants, including residual oil. To identify causes of mortality and potential limiting effects of winter survival for recovery of species, we propose a study to measure survival and mortality sources in harlequin duck and Barrow's goldeneye females. The study would address the following questions:

- does overwinter survival limit population growth of sea duck species?
- what are sources of mortality? Is mortality higher in oiled habitats than unoiled habitats?
- what are frequency and distance of wintering sea ducks movements? Do they move among oiled and unoiled habitats?
- how are sea ducks distributed throughout the Sound?
- do harlequin ducks marked during fall and winter breed in Prince William Sound?

Methods. Sea ducks would be captured during fall by a variety of techniques, potentially including: driving molting flocks, net guns, rocket nets on roosting sites, mist nests, night-lighting, and capturing from underwater using scuba or rebreather technology. Females would be outfitted with radio-transmitters. Only females would be assessed because their survival dictates population dynamics. Capturing, marking, and tracking birds will be conducted cooperatively with Alaska Department of Fish and Game investigators studying harlequin ducks.

Transmitters equipped with mortality switches would be implanted in the body cavity with an external antenna. Surgeries would be conducted by a certified veterinarian. Radio telemetry flights would be conducted weekly through winter and early spring. Flights would locate each marked individual and note status, flock size, coordinates, and general habitat. For birds indicated as dead, the carcass would be recovered by boat or float plane as soon as possible. Collected carcasses would be examined for causes of mortality.

We propose analyzing existing data from boat-based marine bird population surveys conducted in March (1972-73, 1984-85, 1990-91, 1993) and aerial surveys conducted in March and October (1989-90) by the U.S. Fish and Wildlife Service to clarify winter distribution of sea ducks in the Sound. Combining survey data with existing information on shoreline type will also allow us to formulate hypotheses concerning habitat factors affecting distribution.

Condition and Foraging Ecology

Objectives: We propose a foraging ecology study that would assess variation in physiological condition and prey species of harlequin ducks, Barrow's goldeneyes, and white-winged scoters. Also, potential competition within the sea duck community and with other benthic foragers (e.g., sea otters) would be determined. The study would answer the following specific questions:

- does condition (as a measure of health) change through winter? Is condition related to habitat (including oiled vs. nonoiled)?
- what taxa and size classes of prey are sea ducks eating in the winter?
- does potential competition exist among benthic foraging predators (including sea ducks, sea otters, invertebrate predators) for food items of sea ducks?
- are prey species abundances linked to specific habitats, including oiled vs. unoiled habitats?
- does energy expenditure (as measured by foraging behavior) differ among habitats (including oiled vs. unoiled)?

Methods. We would assess condition and diets of female harlequin ducks, Barrow's goldeneyes, and white-winged scoters by collecting approximately 40 individuals of each species annually, for 2 or 3 seasons. Upon collection, the digestive tract would be dissected immediately, and contents of the esophagus, proventriculus, and gizzard would be preserved and stored separately. In the laboratory, foods would be sorted, identified, analyzed for oil, and their volume and dry weight measured. Body composition analysis would be conducted as described by Esler and Grand.

We would assess foraging behavior by observing marked birds for periods during which the proportion of time spent foraging would be measured. Time spent foraging during these periods would be measured either through continuous observations, or by sampling behavior instantaneously at pre-determined intervals (e.g. every 20 seconds). By identifying habitats used by focal birds at each sampling point, we would also quantify time spent foraging in different habitats.

C. Schedule

To adequately understand factors influencing sea duck populations and annual variation, a study of 5 years or longer should be initiated. Field work supported with FY95 funds would begin in fall 1994 and continue through March 1995. Annual reports would be completed by the winter following field work.

D. Technical Support

Contracts for laboratory work will be required for physiological condition and digestive tract content analysis, and for consultation with a statistician to insure appropriate analysis techniques are used.

E. Location

Prince William Sound, at study sites to be determined in conjunction with investigators studying sea otters and benthic invertebrate communities.

PROJECT IMPLEMENTATION

This project would be implemented by the Alaska Science Center of the National Biological Survey, and by the U.S. Fish and Wildlife Service. Personnel in these agencies have extensive experience studying population dynamics of waterfowl in Alaska.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This sub-project is a joint effort by biologists in two trust agencies (NBS and USFWS). Success of this project also relies on other investigators within the Nearshore Project collecting information on (1) prey abundance, size class, and distribution and (2) foraging ecology of other predators of benthic invertebrates such as sea otters, octopus or sea stars. We are in close contact with potential investigators of these projects, and with investigators of the harlequin duck breeding population. We plan to share proposals and results, and to realize cost-efficiencies by working at common field sites.

These studies of wintering sea duck ecology in Prince William Sound would be most valuable as concurrent, integrated investigations. For example, studies of foods and trophic interactions would identify possible food limitations and pathways for pollutants, and seasonal changes in condition. Survival studies are necessary to link these factors to risk and causes of mortality. Habitat studies could further advance our understanding by identifying underlying, proximate causes of variation in food, behavior, and condition that may affect survival.

FY 95 BUDGET (\$K)

Personnel	165.4
Travel	8.0
Contractual	129.5
Commodities	12.0
Equipment	66.3
Subtotal	381.2
Gen. Admin.	33.9
Total	415.1

Sea Otter Abundance and Distribution, Food Habits and Population Assessment

Project Number:	95025B
Restoration Category:	Research (new)
Proposed By:	National Biological Survey
Lead Trustee Agency:	DOI
Cost FY 95:	\$168,100
Cost FY 96:	\$138,500
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sea otter

INTRODUCTION

Sea otters are the most abundant of the Alaskan marine mammals affected by the *Exxon Valdez* oil spill (EVOS). They were hunted almost to extinction in the 17th and 18th century, but have since reoccupied most of their original range in Alaska, including areas in Prince William Sound (PWS). Otters play a major role in structuring the nearshore community through predation on nearshore marine invertebrates.

Sea otters were severely injured by the EVOS, with an estimated initial loss throughout the spill area of approximately 4000 animals. Sea otters in PWS suffered the greatest effects, and oil-related injury to the otters residing in western PWS appeared to persist through at least 1991. Although there is evidence that the health of the otters has improved since 1991, there is uncertainty about the status of recovery of sea otters in oiled areas. Specifically, concerns arise in regard to 1) relatively low densities and 2) poor survival of juvenile sea otters in western PWS. Survival rates of juveniles in western PWS were significantly lower than in non-oiled areas in both 1990-91 and 1992-93. However, survival rates for both areas improved in 1992-93 compared to 1990-91. Low densities of sea otters are observed in areas that were heavily oiled relative to lesser or non-oiled areas. For example, densities of sea otters around northern Knight Island and Naked Island are relatively low compared to the densities observed around Green Island. Factors (including oil effects) causing varying otter densities and juvenile survival rates are not understood. Availability of prey for sea otters may be a contributing factor.

Further concern over the health of sea otters in oiled areas arises from differences in blood values of sea otters living in oiled versus non-oiled areas of PWS. We have observed increased levels of blood serum enzymes indicative of liver disorders (ALT, GGT), and white cells (eosinophils) that may be related to subclinical disease from oil exposure. The increased levels of serum enzymes are consistent with changes observed in oiled otters exhibiting kidney and liver pathologies at the rehabilitation centers. The differences between otters in oiled and non-oiled areas persisted through 1992; no blood samples have been collected since then.

This project is a component of an integrated effort to examine recovery of injured species in the nearshore ecosystem. We address the status of recovery of sea otters in PWS and the interactions among sea otters and other species in the nearshore community that have potentially been injured by oil exposure. Specific accomplishments of this project will include evaluation of 1) the extent of recovery, 2) factors contributing to differences in densities, 3) health and condition, and 4) food habits of sea otters among areas in PWS that vary in oiling and in densities of otters.

Sea otter studies previously funded by the Trustees include NRDA Marine Mammal Studies #6 & #7, and Restoration Project 93043, conducted on sea otters in PWS from 1989 through 1994. This project represents a logical continuation of certain elements of those studies.

NEED FOR THE PROJECT

This project will 1) monitor recovery of sea otters through the collection of data on the abundance and distribution, 2) assess possible chronic effects of oil exposure on sea otters in oiled areas of PWS, and 3) enhance our understanding of the role that sea otters play in structuring nearshore communities that have been impacted by the EVOS. Information will be obtained on factors limiting recovery of sea otters and on alterations in the nearshore community affected by or affecting sea otters.

PROJECT DESIGN

This project has 3 elements:

1. **Surveys:** to evaluate abundance, distribution, reproductive rates, and mortality.
2. **Health and Condition:** to evaluate sea otter body condition and health and possibly hydrocarbon burdens (if warranted, based on shellfish and sediment hydrocarbon results).

3. Food Habits: to evaluate the role of sea otters as a top-level predator in the nearshore community.

A. Objectives

1. Surveys

- a. Monitor sea otter recovery: conduct a survey of sea otter abundance and distribution in PWS.
- b. Conduct seasonal surveys of sea otter abundance and distribution at specific study sites.
- c. Conduct a survey of sea otter reproductive rates, based on ratios of pups to adults.
- d. Quantify age distribution of sea otters dying over the winter at Green Island.

2. Health and Condition

- a. Assess body condition of sea otters.
- b. Assay markers of immune function in sea otters.
- c. Collect fat tissue samples for potential analyses of hydrocarbon levels.

3. Food Habits

- a. Quantify prey selection and foraging efficiency of sea otters at specific study sites.

B. Methods

Study sites will be selected based on discussions with other investigators in the integrated nearshore ecosystem project. We anticipate identifying up to 4 sites in PWS to be the focus of this project.

1. Surveys

- a. PWS-wide aerial survey (methods as developed under Restoration Study # 93043) of distribution and abundance, summer 1995. This element of the project is for monitoring recovery.
- b. Site-specific aerial surveys of distribution and abundance, quarterly (spring, summer, fall, winter 1995).
- c. Boat-based survey of relative abundance of adults and pups, to estimate reproductive rates. The ratio of the number of pups to adults will be estimated and compared to existing data on pre- and post-spill ratios.
- d. Carcass recovery - survey Green Island shorelines in early spring to recovery beach-cast carcasses, and estimate age at death from reading of premolar tooth.

2. Health and Condition

- a. Capture sea otters at study site - collect body measurements (weight, length, and girth), blood, fat biopsy for possible hydrocarbon analysis, premolar tooth to estimate age; and flipper-tag otters with unique color-coded tags to allow identification of individuals.
- b. Evaluate immune function through 1) B & T cell activities, including levels of IGG, IGE, IGA, and IGM as indicators of humeral immunity, and 2) blast transformation assays to measure T-cell activities. Laboratory work to be done in cooperation with Dr. Alan Rebar at Purdue University.
- c. Evaluate blood CBC's and chemistries - laboratory work to be done by PML laboratories.

3. Food Habits

Observations of foraging behavior at study sites (observe all otters present, with preferential collection of data on flipper-tagged individuals when possible). Data to include prey items, prey sizes, # prey recovered/dive and dive times. Foraging data to be collected twice, in late winter and late summer of 1995.

C. Schedule

TIME	ACTIVITY
FALL 1994	1. DEVELOP DETAILED STUDY PLAN - WORKING IN CLOSE CONJUNCTION WITH OTHER INVESTIGATORS TO MAXIMIZE EFFICIENCY OF DATA COLLECTION 2. PERMIT APPLICATION - OTTER CAPTURE
SPRING 1995	1. CARCASS RECOVERY - GREEN ISLAND 2. SITE SPECIFIC SURVEYS OF DISTRIBUTION AND ABUNDANCE
SUMMER 1995	1. SURVEY OF DISTRIBUTION AND ABUNDANCE - ALL PWS 2. SITE SPECIFIC SURVEY OF DISTRIBUTION AND ABUNDANCE 3. OTTER CAPTURE AT SPECIFIC SITES 4. FORAGING OBSERVATIONS AT SPECIFIC SITES
FALL 1995	1. SITE SPECIFIC SURVEY OF DISTRIBUTION AND ABUNDANCE
WINTER 1996	1. SITE SPECIFIC SURVEY OF DISTRIBUTION AND ABUNDANCE 2. FORAGING OBSERVATIONS AT SPECIFIC SITES
SPRING 1996	1. COMPLETE DATA ANALYSIS AND WRITE REPORTS ON 1ST YEAR WORK 2. CARCASS RECOVERY - GREEN ISLAND
SUMMER 1997	1. SURVEY OF DISTRIBUTION AND ABUNDANCE - ALL PWS

D. Technical Support

The primary need for technical support is integration of data collected on other components of the Nearshore Ecosystem project with data collected on sea otters.

E. Location

The project will be conducted in western PWS. Communities that will be involved or affected include New Chenega (may provide a base for winter operations), Cordova and Whittier. The extent of involvement of these communities will depend on finalizing the project design, in coordination with other investigators, to identify specific study sites.

PROJECT IMPLEMENTATION

This component of the Nearshore Ecosystem project will be implemented and overseen by staff of the sea otter project, Alaska Science Center (ASC), NBS. Most of the equipment needed for project activities outlined herein is already owned by the ASC.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will be a component of and will coordinate closely with other projects in the Nearshore Ecosystem project.

FY95 BUDGET (\$K)

Personnel	46.7
Travel	15.0
Contractual	75.4
Commodities	10.7
Equipment	8.0
Subtotal	155.8
Gen. Admin.	12.3
Total	168.1

Pigeon Guillemots and River Otters as Bioindicators of Nearshore Ecosystem Health in Prince William Sound

Project Number:	95025C
Restoration Category:	Research (new)
Proposed By:	Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks
Lead Trustee Agency:	DOI
Cost FY 95:	\$189,200
Cost FY 96:	\$189,200
Total Cost:	Unknown
Duration:	4 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pigeon guillemot, river otter, intertidal organisms

INTRODUCTION

This study is relevant to EVOS ecosystem research because it is designed to develop a better understanding of how petroleum hydrocarbon pollution affects the nearshore marine environment in Prince William Sound (PWS). Results from this study will allow us to test biostatistical models that predict ecosystem health and environmental deterioration. Use of bioindicators will lead to a better understanding of ecosystem processes in PWS. Our proposal describes a research approach for assessing the biological and ecological significance of contaminants present in the environment. In this research our focus is the pigeon guillemot (*Cephus columba*) and river otter (*Lutra canadensis*) as indicators of environmental stress.

The guillemot and river otter models will be used as upper trophic level sentinels of bioavailable contaminants, such as oil, and as surrogates to estimate the potential exposure and risk to other organisms that are components of the PWS nearshore ecosystem. This research approach utilizes biomarkers (biochemical and cellular indicators of exposure), reproduction rates, and data on mortality to identify and quantify the present level of variability within the PWS ecosystem. This approach is necessary because evaluation of the potential for exposure to contaminants in the environment is extremely complex due to the differences in the biological availability of contaminants at different trophic levels and varying toxicological interactions within exposed organisms.

Focusing on the biological responses in indicator species overcomes many of the limitations that plague chemical analysis of the environment. While measuring body burdens is an important aspect of using a biomonitor, equally important is the measurement of biomarkers because they:

1. Provide evidence of exposure to compounds that do not bioaccumulate or are rapidly metabolized;
2. Integrate the toxicological interactions resulting from exposure to complex mixtures of contaminants;
3. Present a biologically relevant measure of the cumulative adverse effect; and
4. Measure early responses of organisms to toxicant exposure and serve as short-term predictors of long-term adverse effects.

By proper selection of a bird and a mammal from an upper trophic level, specific sources and routes of exposure can be identified. Analysis of biological markers in birds and mammals may offer a means of identifying exposures due to toxic sites from those due to other natural exposures. In guillemots we will measure induction of immune system, acute phase proteins, and cytokines as biomarkers. We will compare our results from guillemots with previous work on other bird species, our PWS work on river otters (*Lutra canadensis*), and results from current research on guillemots in Kachemak Bay. The earlier work on river otters and our current work on guillemots in Kachemak Bay will validate our study of guillemots and river otters in PWS and our biostatistical model. This model is far more detailed than those for any bird, and maintains a mammalian component for human comparisons. While guillemots are easier to capture and handle than otters during the breeding season, including otters as a component of the research may be essential because guillemots are principally available during nesting, whereas otters are year-round residents.

The purpose of our study is to assess whether populations of pigeon guillemots and river otters in PWS are recovering from the effects of the *Exxon Valdez* oil spill, and, if not, why this might be the case. We will test hypotheses that relate to possible routes of hydrocarbon contamination in the top-level predators, and use biomarkers to assess the effects of such contamination on the health of these populations. Finally, our study will provide information necessary to restore populations of guillemots and river otters, should such actions be required.

Our project is closely integrated with other research designed to assess the effects of the oil spill on nearshore vertebrate predators and their prey. We have proposed the only project that will evaluate predators that feed primarily on marine fishes in the nearshore environment. Moreover, results from our investigations are essential to provide an understanding of whether these injured resources are recovering, and what role lingering effects from oil contamination might play in the overall health of the Prince William Sound ecosystem.

NEED FOR THE PROJECT

Pigeon Guillemots

We are currently developing pigeon guillemots as an avian bioindicator for coastal ecosystems in Alaska. This research is currently underway in Kachemak Bay, Alaska, and will provide crucial baseline information for the proposed work in PWS. Guillemots are the most neritic members of the marine bird family Alcidae, which includes the murre, puffins, and auks. Pigeon guillemots are the best-suited species for monitoring nearshore ecosystem health for several reasons: (1) they are a common and widespread seabird species breeding in coastal Alaska, and in PWS specifically; (2) they forage within 5 km of the nest site in the subtidal and nearshore zones; (3) unlike most seabird species, they do not breed in large, dense colonies; (4) they raise their young almost entirely on fish, preying primarily on intertidal and nearshore bottomfish (e.g., blennies, sculpins) and on nearshore schooling fish (e.g., sandlance); (5) the one- or two-chick broods are fed in the nest until the young reach adult body size.

Guillemots first breed at 2 years of age and adults have high annual survivorship (85%). Young guillemots normally return to the natal area to breed. Nest site fidelity of breeding pairs is high and even in instances when pairs relocate nests, the distances involved are usually small (< 30 m). Eggs are laid in a wide variety of natural crevices and holes, but most nest sites in the study area are located in cavities in rock masses. Eggs are usually laid about 50 cm from the entrance of the nest crevice, thus eggs, chicks, and attending adults are frequently accessible for data collection. Guillemots are unusual among alcids in that they normally lay two-egg clutches and raise two chicks per nesting attempt. Guillemots carry whole fish in their bills to the nest-site crevice to feed their young. Thus individual prey items can be identified, weighed, measured, and, if necessary, collected for contaminant analyses.

Other potential avian bioindicators of Alaska coastal ecosystems are unsuitable for several reasons. Larus gulls (e.g., glaucous-winged and herring gulls) have been used as models for studies on the sublethal effects of crude oil on marine birds and are widespread and common components of Alaska coastal ecosystems. But gulls frequently feed at dumps and scavenge fish offal from fishing vessels where exotic contaminants may be encountered. Larus gulls may also commute long distances to utilize these food sources; consequently the source of anthropogenic contaminants in the diet may be difficult to determine. Other alcid species (e.g., puffins, murre) and kittiwakes (*Rissa tridactyla*) forage offshore (up to 100 km from the nest site) on pelagic schooling fish and are restricted to breeding at a few relatively inaccessible colonies in the study area. Thus they are inappropriate bioindicators of nearshore ecosystem health and potential contaminants in food webs close to breeding colonies. In addition, these species are sensitive to social stimulation at the breeding colony. Thus direct mortality from plumage oiling can result in reduction of colony-wide reproductive success even in the absence of a contaminated food supply. Other alcids that forage in the neritic zone and are noncolonial (e.g., marbled murrelet) may nevertheless forage at considerable distance from nest sites, and active nests high in mature timber are extremely difficult to locate and monitor.

Guillemots have served as subjects in previous studies to assess the effects of ingested crude oil on marine birds. Nestling black guillemots (*Cepphus grylle*), a very closely related sibling species of the pigeon guillemot, were fed single doses of weathered South Louisiana crude oil (WSLC) and subsequently monitored in their natural nest site where they were cared for by their parents. These experiments demonstrated that single doses of as little as 0.1 ml WSLC resulted in declines in growth rates, increases in plasma sodium levels and increases in nasal and adrenal gland masses. The effects of the single dose were not transient, as nestlings that were dosed at roughly two weeks post-hatch were 20% lighter than controls at five weeks of age (just prior to fledging). Such persistent sublethal effects may have serious consequences for post-fledging survival. Peakall et al.'s study clearly demonstrates that guillemot nestlings living normally in their chosen habitat are tolerant to the handling and disturbance associated with assessing pollutant toxicity.

We will monitor blood parameters in pigeon guillemots breeding at Naked Island (oiled area) and Fool Islands (non-oiled area) in Prince William Sound. Data on population size, reproductive success, prey composition and provisioning rates of breeding guillemots will be collected at these same sites as part of an on-going research project conducted by the Fish and Wildlife Service and directed by Dr. David Irons. Collection of blood samples nestling and adult guillemots will be coordinated closely with Dr. Irons' field crew. Naked Island supports the highest breeding densities of guillemots in PWS and a breeding population that is adequate for the proposed research. The following parameters will be measured at accessible guillemot nests, in coordination with Dr. Irons' studies, as indices of parent-offspring productivity: (1) chick feeding rates; (2) chick meal size; (3) taxonomic composition of chick diets; (4) biochemical composition of chick food items; (5) chick growth rates and body composition; (6) nestling survival; and (7) fledging age, body mass, and body composition. Productivity will be compared with blood parameters used to monitor contaminant exposure. Nondestructive indices to stress induced by petroleum hydrocarbon ingestion will be used, such as levels of selected plasma immunoglobulins, blood plasma proteins, cell counts, and interleukin levels in blood of adults and chicks, body mass and body composition of adults and chicks, chick growth rates, and fledgling mass. These data will then be used to evaluate the factors that limit guillemot productivity. The results of this research project will provide us with the background necessary to use guillemots as avian indicators of nearshore ecosystem health in PWS.

The population status of pigeon guillemots in PWS and the northern Gulf of Alaska has been of concern for nearly a decade due to declines in number of adults observed on survey routes. Low fledging success has been attributed to changes in the abundance and distribution of forage fish resources within foraging range of guillemot nests. There is a troubling lack of information on the factor(s) responsible for poor reproductive performance.

River Otters

River otters inhabiting marine environments make extensive use of, and concentrate their activities in intertidal and subtidal zones. These high trophic-level carnivores are long-lived (> 12 years of age), and occur at densities of 0.2-0.8 otters/km of shoreline throughout the Gulf of Alaska. River otters are extremely sensitive to aquatic pollutants, yet continued to reside within the area of oil-contaminated shorelines in Prince William Sound, Alaska following the *Exxon*

Valdez oil spill. These characteristics make river otters an excellent model for assessing the effects of marine pollution on mammals, and provide an overall index to the health of the nearshore ecosystem.

River otters living in marine environments consume a diet dominated by marine fishes, which they prey upon in intertidal and subtidal zones, although they also consume a wide variety of marine invertebrates. Such nearshore areas are the most often affected by pollution. For instance, oil spilled from the *Exxon Valdez* contaminated extensive areas of the intertidal and subtidal environments, which was reflected in a loss of dietary diversity for otters inhabiting oil-contaminated shorelines. Likewise, river otters living in oiled areas exhibited a significantly lower body mass (when controlled for sex and total body length) than did otters inhabiting oil-free areas. Otters have extremely large home ranges (20-40 km of shoreline), and hence integrate the effects of pollution over wide areas.

Population dynamics of European otters (*Lutra lutra*) in coastal areas have been linked to the abundance of marine fishes; this is also likely the case for river otters inhabiting PWS. We previously demonstrated that the diversity of otter diets declined significantly following the *Exxon Valdez* oil spill. Similarly, the body mass of otters was significantly lower on oiled, compared with non-oiled, areas of PWS. Unfortunately, we were unable to determine whether such changes were caused by toxicological effects of oil on otters, changes in prey availability, or loss of habitat. We were unable to resolve this question because too few otter study sites were also sampled by those studying fishes. We have overcome this problem in the present study by close coordination with the sea urchin proposal (95087). We will share study areas with this project, and Steve Jewett has agreed to sample fishes along the same underwater transects used to sample urchins -- this will add no additional cost to either proposed study. Fish along transects will be identified to the lowest possible taxon; gadiforms, coitids, and other fish will be speared opportunistically. These samples will be frozen and archived for potential future analyses. If biomarkers from otter blood indicate exposure to oil and no oil residue is recovered from the pelage of otters, then we will evaluate these fish for oil contamination (e.g., cytochrome P-450 analysis). Oil contaminated fishes likely persist in PWS, but we believe contamination of pelage and subsequent grooming by otters is a more likely route of oil exposure). Although river otters do consume mussels (*Mytilus edulis*) in PWS, we were able to reject otters feeding on mussels as a hypothesis to explain elevated biomarkers in river otters.

We will evaluate changes in population trends of river otters by examining the frequency of latrine site abandonment on oiled and non-oiled areas. Kruuk et al. demonstrated a strong positive relationship between number of resident females and number of active holts (latrine sites) for European otters living in a marine environment. Likewise, Testa et al. showed that number of active latrines varied with estimated population size for river otters in PWS; however, too few areas were sampled to establish a regression line between these variables. Nonetheless, it is likely that abandonment of latrines provides a useful index to otter abundance, and can be used to evaluate trends in otter populations. Indeed, Duffy et al. documented that river otters throughout oiled areas of PWS abandoned latrine sites at a rate over three times greater than did otters inhabiting non-oiled areas. We will not be sampling all of the same areas we previously examined because of integration with other studies of

vertebrate predators in the nearshore environment. If differences in oiled and non-oiled areas still exist, it would be possible in subsequent years to evaluate the same sites that we sampled in 1991 to compare current values against that benchmark. Measuring trends in otter populations will not increase the costs of this study because we must evaluate these sites in the process of setting live-traps for otters in order to collect blood samples for biomarker assays.

We previously developed a nonlethal method for evaluating the effects of marine pollutants (in this instance, crude oil) on the blood-enzyme chemistry of river otters. We first noted that blood haptoglobins (an acute-phase protein) were elevated in otters inhabiting areas where crude oil was prevalent one year following the oil spill. Even two years after the oil spill and a major effort to clean oil-contaminated shores, we were able to construct a biostatistical model, using logistic regression, in which we classified > 86% of river otters correctly as having been captured in oiled or non-oiled zones. This highly sensitive model used only blood values for haptoglobin, interleukin 6 (a cytokine), and AST (a liver enzyme). Our approach has already been extended for evaluating other marine mammals, and may be applicable to other vertebrates, especially marine birds. The strength of this line of research is that we have already developed the expertise necessary to live-capture river otters, have base-line data from oiled and non-oiled areas throughout Prince William Sound, and have a predictive model that assesses the effects of oil contamination on otters, thereby providing an index to environmental health. Coupling our knowledge of otters with similar physiological data for pigeon guillemots will provide a sensitive tool for examining the health of nearshore ecosystems.

PROJECT DESIGN

A. Objectives

This proposal's overall goal is to identify the internal dosage of oil-related pollutants received by piscivorous birds and mammals foraging in the nearshore ecosystem of PWS, Alaska through measuring key parameters associated with biochemical toxicity. Thus, we will quantify the biochemical changes in birds and mammals inhabiting this fragile ecosystem. Guillemots and river otters will provide insight into the pathways and effect (if any) on food webs and the long-term health of the ecosystem. The objectives of this study are to:

1. Identify guillemot nest sites and river otter latrine sites;
2. More accurately assess the effects of oil exposure. It is our intent to collect blood from guillemots and river otters in several areas of PWS to establish control areas;
3. Use blood samples from the guillemot and river otter populations to determine levels of acute phase blood proteins such as haptoglobin, albumin and metallothionein, which are indicative of exposure and tissue damage. We also will measure cytokines such as IL-1 and IL-6 and liver enzymes such as AST;

4. Supplement our molecular work by cellular studies such as red cell volume, hematocrits and immune functions (Heinz bodies will be looked for in guillemot and river otter samples);
5. Generate risk-assessments based on these biomarkers; and
6. Measure trophic level using stable isotope analysis of guillemot samples and plants and scats from river otter latrine sites.

This proposal will produce background values for selected biomarkers and allow the development of "blood associated indices" of environmental stress in mammals and birds. These indices will be useful in comparing current and future levels of petroleum hydrocarbon contamination in PWS.

B. Methods

Pigeon Guillemots

Field studies will be conducted during the 1995, 1996, and 1997 breeding seasons in PWS, Alaska. Approximately 800 pigeon guillemots nest along the shores of Naked Island. Seventy-five active and accessible nests will be located and marked during early incubation in each of the three breeding seasons, in coordination with on-going U.S. Fish and Wildlife Service studies of guillemot reproductive success in oiled and non-oiled areas of PWS. These nests will be closely-monitored until the young fledge or the nesting attempt fails. Known-age chicks will be weighed regularly to determine individual growth rates throughout the nestling period. Blood samples (1 ml) will be collected by brachial vein puncture from each nestling at ages 20 and 30 days post-hatch (guillemot chicks normally fledge at 30-40 days post-hatch). These blood samples will be collected using SOPs developed by us during the *Exxon Valdez* spill studies to preclude sample contamination. Blood samples will be analyzed for molecular and cellular biomarkers (e.g., characteristic morphological lesions of red blood cells associated with hemolytic anemia caused by oil ingestion). Total body fat of chicks at 20 and 30 days post-hatch will be determined by noninvasive measurement of total body electrical conductivity. Body mass and total body fat measurements will be used to develop a condition index for each chick at 20 and 30 days post-hatch.

The impact of contaminant exposure on breeding adults will be monitored using a combination of direct and indirect methods. Attentiveness of adults will be monitored during the incubation period. Frequency of chick meal delivery and meal size will be determined during the chick-rearing period by a combination of monitoring adult nest visitation rates and periodic weighing of chicks. Individual variation in exposure of adults (and chicks) to petroleum hydrocarbons will be monitored by periodically collecting food samples from adults as they return to the nest site to feed chicks and by collecting prey samples at sea. In the lab, samples of chick food will be analyzed to determine levels of aliphatic and aromatic hydrocarbon fractions using an Iatroscan MK-5 TLC/FID Analyzer System. During the chick-brooding period (0-7 days post-hatch), adult guillemots will be captured in the nest crevice, banded for later identification, and blood samples (1 ml) collected from the brachial vein. Blood samples

will be analyzed for molecular and cellular biomarkers of contaminant exposure using the same techniques applied to chick blood samples. These measurements will allow us to monitor the impact of various levels of contaminant exposure on physiological condition of chicks and foraging efficiency of adults.

River Otters

Otters, which are relatively abundant in PWS, will be captured using Hancock live traps placed on trails at latrine sites and monitored by means of a trap transmitter (Telonics, Mesa, Arizona, USA) that signals when a trap was sprung. We have used this method successfully in the past. The otter initially will be immobilized in the trap with a hand injection of ketamine hydrochloride (11 mg/kg estimated body weight, Sigma, St. Louis, Missouri, USA) and placed in a drugging box. Weights and measurements will be taken and the blood sample drawn from the jugular vein. Sexes will be distinguished by the relative position of urogenital openings and palpitation of the baculum. Age determinations will be based on tooth wear and overall size of otters.

Analyses

During the past 15 years, xenobiotics have been shown to alter immune function. Environmental chemicals interact with various parts of this complex system resulting in either suppression or hypersensitivity of immune activity and surveillance. A panel of biomarkers, including leukocyte counts, macrophage function, electrophoretic measurements of serum immunoglobins, and ELISA assays of interleukins will provide data on the health status of organisms and permit comparison of species.

At UAF, we will perform haptoglobin assays, IL-1 and IL-6 assays, and immunoglobulin typing assays for the blood samples collected during this project. Cell counts will be performed by NBS contracted lab and macrophage function assays will be developed.

The following biomarker analyses will be performed on the samples: blood plasma protein and liver enzymes, cell counts and Heinz bodies, and interleukin levels. The following organism analyses will be performed for guillemots: reproductive success, nest and site abandonment, trophic level using stable isotope ratios of guillemot tissues and prey.

In the area of data analysis and interpretation, we plan on linking our data with the results on sea otters and nearshore invertebrates in PWS. Proposed studies on invertebrates, sea otters, and ours on guillemots and river otters in PWS gives these studies a holistic ecosystem approach. All data from this study will become public information. The data will be forwarded to the EVOS Trustee Council in journal format for archiving. Also, the data will be available to the public through the use of peer reviewed journals. Any different format will be mutually agreed to.

C. Schedule

Field work in Prince William Sound will be conducted during spring and summer 1995, 1996, and 1997. Data collection during three field seasons will be necessary to provide minimal information on interannual variation in reproductive success and blood chemistry of guillemots and morphometrics and blood chemistry of river otters. Guillemots normally lay eggs from late May to late June and raise their young during July and early August. Active, accessible nests of the study species will be located and marked early in the incubation period during late May and early June. Marked nests will be checked daily during the hatching period to determine hatching date, and chicks will be banded soon after hatching so that individual growth rates can be monitored throughout the nestling period. Blood samples from chicks will be collected throughout the nestling period. Chicks will be monitored throughout the nestling period to determine growth rates, fledgling age and mass, and survival until fledging. River otters are most easily live-trapped in late April and early May; we will concentrate our efforts during this period.

Following the field season, guillemot and river otter blood samples will be analyzed in the lab. These analyses will be completed before the next field season to determine the results prior to collecting additional samples from the field. A draft annual report will be prepared in April and a final report will be submitted in June. Following the analysis of samples collected during the 1997 field season, data collected during the three field seasons will be analyzed by May 1998 for relationships between blood bioindicators and reproductive success for guillemots, and between morphometrics and blood chemistry for otters. The results of these analyses will be prepared in manuscript form and submitted by the end of FY 1998.

D. Technical Support

Laboratory analyses of the blood chemistry of guillemots and river otters will be conducted in the laboratory of the Co-PI (LKD). Standard blood clinical panel and ELISA analyses of oil on pelage and plumage will be subcontracted to other laboratories. No new laboratory equipment will need to be purchased for the proposed research with funds provided by the grant. A laboratory technician will be employed to help the Co-PI and graduate research assistant with IG and HP analyses in blood, and with performing of routine laboratory analyses.

E. Location

The proposed field work will be conducted in PWS. PWS supports accessible breeding population of guillemots that are more than adequate for the proposed research. Field work on guillemots will be conducted at breeding colonies on Naked Island, Fool Island, and Jackpot Island. Approximately 800 pigeon guillemots nest along the shores of Naked Island. The Naked Island base camp would offer an ideal base for field studies on guillemots and Naked Island supports the highest breeding densities of guillemots in PWS. Fool Island has approximately 80 guillemot nests and Jackpot Island has about 60 guillemot nests and pairs are breeding at high densities in both sites. Naked Island also supports high densities of river otters, and we already have baseline data for otters on Naked Island and northern Knight

Island.

The at-sea foraging distribution of pigeon guillemots near Naked Island, Fool Island, and Jackpot Island has been the subject of previous study, as has the species composition of the diet. A field camp operated by the U.S. Fish and Wildlife Service is available for field workers on Naked Island and is within walking distance of colonies where adequate numbers of accessible guillemot nests are available.

PROJECT IMPLEMENTATION

The proposed research will be implemented by the University of Alaska Fairbanks, with assistance from and in cooperation with U.S. Fish and Wildlife Service and Alaska Department of Fish and Game biologists with expertise on the proposed study species in the proposed study area. The PI (D. D. Roby) has extensive experience with studies of the reproductive biology of high latitude seabirds and the relationship between nestling growth and productivity. L. K. Duffy has extensive experience conducting blood analyses, including previous oil spill research. R. T. Bowyer has developed and published a habitat model that will help insure the capture of river otters (by trapping in the most productive areas) and has numerous other publications on river otters. The PI and Co-PI (LKD) currently have in their laboratories the analytical equipment necessary to accomplish the proposed laboratory analyses and they are familiar with the relevant analytical procedures. To the PIs' knowledge, the expertise and equipment necessary for the proposed research are not available within the federal and state agencies that compose the Trustees Council. The PIs will be assisted by a Graduate Research Assistant (Ph.D. candidate), Field Technicians, and undergraduate field assistants who will be carefully selected from the applicant pool as qualified to participate in the proposed research.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The research described in this proposal dovetails nicely with on-going research to assess factors limiting recovery of seabird and mammal populations damaged by EVOS. It is also relevant to efforts toward developing seabird and mammal models as upper trophic level sentinels of contaminants and changes in the availability of fish for vertebrate predators. The proposed research approach utilizes biomarkers to help identify and quantify the health of vertebrate predators within the PWS ecosystem. This approach is necessary because of the extreme complexity of assessing contaminant exposure due to temporal and spatial variability and unpredictability in PWS.

Cooperators include Dr. David Irons of the Migratory Bird Branch, U.S. Fish and Wildlife Service. Dr. Irons has had extensive experience working in the field with both guillemots nesting in PWS, and is project leader for on-going studies of the reproductive success and status of these two species in PWS. Close coordination with Dr. Irons' research teams at Naked Island will be essential for the success of the proposed research.

FY 95 BUDGET (\$K)

Personnel	44.5
Travel	9.6
Contractual	54.2
Commodities	52.0
Equipment	12.4
Subtotal	172.7
Gen. Admin.	16.5
Total	189.2

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Algal Competition Limiting Recovery in the Intertidal

Project Number:	95025E
Restoration Category:	Research (new)
Proposed By:	UAF and NBS
Lead Trustee Agency:	DOI
Cost FY 95:	\$205,100
Cost FY 96:	\$215,500 (includes data analysis and report writing costs)
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Cook Inlet - Kenai Peninsula
Injured Resource/Service:	Intertidal organisms

INTRODUCTION

The *Exxon Valdez* oil spill and subsequent clean-up efforts had a major impact on affected intertidal communities as shown by the Coastal Habitat Injury Assessment project (CHIA). During the CHIA studies it was discovered that certain areas and habitats in the intertidal community were particularly sensitive to oiling/clean-up. One of these habitats was the lower intertidal in the highly diverse, sheltered rocky habitats in the Cook Inlet-Kenai Peninsula area (CIK). Normally the annual kelp, *Alaria*, dominates the lower intertidal area during the summer seas on. In spring (around April) the cryptic gametophytes germinate to produce small *Alaria* sporelings. These rapidly growing plants usually outcompete *Fucus* and other perennials in this zone giving rise to a large bed of *Alaria* plants in the lower intertidal. We believe that the oil spill and/or clean-up, occurring in April, significantly damaged either the gametophytes or young sporelings of *Alaria*. These damaged plants died, and the newly created bare substrate was colonized by *Fucus gardneri* and by *Neorhodomela*, both perennial algae. *Alaria* would be slow to recolonize this area because it is an annual and relies on the dispersal of spores from the large, adult sporophytes, which occurred in depressed numbers since the sporelings were destroyed by the spill. *Alaria* probably have a limited dispersal range of a few meters. Therefore, without the fertile adults nearby, spores for the next year's generation were not available. Meanwhile *Fucus* and other slow growing perennials were able to gain an ever increasing foothold. As of the end of the field season in 1991, the shift in community structure still existed.

This shift in the intertidal algal community poses an important ecological question. Will the year round presence of *Fucus gardneri* and other perennials in the lower intertidal now prevent the annual *Alaria* from returning to its natural state as the dominant provider of food and habitat in the lower intertidal community? The proposed new studies would be a continuation of CHIA research and monitoring supplemented by experiments designed to answer specific questions regarding the recovery of *Alaria*.

NEED FOR THE PROJECT

This project addresses the recovery of an injured resource, namely, the lower intertidal sheltered rocky habitat in CIK. Continued studies directed toward injured sheltered rocky intertidal communities are needed to determine how and when recovery may take place. If the shift in the dominant algal type as seen in CIK sheltered rocky algal communities persists, it may have an effect on other organisms along the food chain. Possible repercussions of *Alaria*'s absence could be loss of habitat and food for other marine organisms. *Alaria* is a viable food source for sea urchins which in turn are preyed upon by sea otters.

This project is an outgrowth of the CHIA studies carried out in 1989-1991 in the Cook Inlet Kenai Peninsula area. The results will contribute to our understanding of the limits to recovery in the sheltered rocky habitat in CIK. The study is one that would fit in well with the ecosystem studies of Herring Bay. However, there is no *Alaria* in Herring Bay and, thus, this study can only be done in CIK. The CIK area is unique for this project due to the algal communities in region and to the oiling/clean-up history. This project will benefit by close cooperation with the researchers involved in the Herring Bay Monitoring and Restoration project because of the similar nature of the experiments and data analysis.

PROJECT DESIGN

A/B. Objectives and Methods

1. Quantify the population dynamics and reproductive potential of *Fucus gardneri*, *Neorhodomela*, and *Alaria* on matched oiled and non-oiled sites in CIK sheltered rocky habitats. Counts and measurements of each species will be carried out to determine densities, size classes, and reproductive capabilities.
2. Assess the competitive interactions between *Fucus gardneri*, *Neorhodomela*, and *Alaria* in recolonizing newly created bare substrata on matched oiled and non-oiled sites in CIK sheltered rocky habitats. Reciprocal clearings will be created and revisited for quantification to detect successional interactions between *Alaria*, an annual alga, and *Fucus gardneri* and *Neorhodomela*, perennial algae. Some parallel field experiments will also be set up at Juneau in areas where *Alaria* beds are adjacent to beds of *Fucus*.

3. Monitor the natural recovery of damaged algal communities on matched oiled and non-oiled sites in CIK sheltered rocky habitats. This will be a continuation of the CHIA algal percent cover experiment initiated in 1991 and provides continuity for monitoring the sites.
4. Determine the physiological factors limiting the recruitment of *Alaria*. Laboratory experiments will be set up to test various abiotic elements as limiting parameters for the recruitment of *Alaria*. Of particular interest is the toxic effect of oiling to the growth and recruitment of *Alaria* sporelings and gametophytes.

C. Schedule

During the summers of 1995 and 1996 there will be two trips to CHIA sheltered rocky sites in CIK. A tentative schedule for working days in the field is as follows:

Trip #1: April 15-30

Trip #2: July 25-August 9

A schedule of major landmarks is as follows:

Finalize the study plan	Jan-Mar 1995
Arrange boat charter	Mar-Apr 1995
Field sampling period	Apr-Jul 1995
Laboratory experiments	Apr-Sep 1995
Data compilation	Jul-Sep 1995
Data analysis/interpretation	Sep 1995-Mar 1996
Submit annual report	Apr 1996
Field sampling period	Apr-Jul 1996
Laboratory experiments	Apr-Sep 1996
Data compilation	Jul-Sep 1996
Data analysis/interpretation	Sep 1996-Mar 1997
Submit annual report	April 1997
Submit final report	July 1997

D. Technical Support

Vessel charter to support field work will be necessary. About 20 days per season will be needed. Laboratory facilities will be provided by the Juneau Center, School of Fisheries and Ocean Sciences of UAF.

E. Location

The original study sites used in the CHIA study will be used in this project. CHIA sheltered rocky sites (reference/oiled) in the Cook Inlet-Kenai Peninsula area are: Nuka Bay / McArthur Pass, Chance Cove / Morning Cove, Yalik Bay / Tonsina Bay. An additional site in Juneau will be utilized for the performance of more detailed experiments examining competition between *Fucus* and *Alaria*.

PROJECT IMPLEMENTATION

This project should be implemented by the University of Alaska in cooperation with the National Biological Survey as part of the NBS nearshore recovery research. The University already has an extensive data set on these sheltered rocky sites in CIK, including data on the percent cover and biomasses of *Fucus*, *Alaria* and other intertidal algae. This proposed study will continue an important aspect of the CHIA monitoring by updating the last information from the 1991 field season.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is closely coordinated with the past CHIA studies in CIK and with the proposed continued monitoring of the CIK intertidal areas. The project is also linked with on-going assessments being conducted by NBS in the Kenai Fjords National Park. In addition there will be close coordination and cooperation with the Herring Bay Restoration and Monitoring studies with respect to experimental design and data analysis.

FY 95 BUDGET (\$K)

Personnel	121.5
Travel	8.2
Contractual	46.4
Commodities	3.0
Equipment	4.5
Subtotal	183.6
Gen. Admin.	21.5
Total	205.1

The Availability and Utilization of *Musculus* spp. as Food for Sea Ducks and Sea Otters

Project Number:	95025F
Restoration Category:	Research (new)
Proposed By:	Coastal Resources Associates, Inc. and UAF
Lead Trustee Agency:	DOI
Cost FY 95:	\$5,500
Cost FY 96:	\$0
Total Cost:	\$5,500
Duration:	1 year (additional studies may be proposed for FY 96 based on outcome of FY 95 data analysis)
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sea otter and harlequin duck

INTRODUCTION

This project will examine the utilization of *Musculus* by sea ducks and sea otters in Prince William Sound. *Musculus* spp. are small mytilid mussels that live attached to eelgrass and algae. Large numbers of *Musculus* recruit to selected eelgrass beds within the Sound each spring, and can reach densities of 40,000 or more per square meter. By fall, most of the mussels reach about 1 cm in length. The vast majority of the mussels disappear over the winter. Densities of larger *Musculus* (greater than 1 cm) are seldom greater than 10 per sq. meter. These small mussels provide a potentially valuable food source for both sea otters, and (more likely) sea ducks.

Monitoring of *Musculus* densities on eelgrass has been carried out as part of the subtidal coastal habitat studies (S. Jewett and T. Dean, Principal Investigators), and will likely be continued as part of a subtidal monitoring program in FY 95.

NEED FOR THE PROJECT

Musculus provide an important potential food source for sea ducks and otters. Evidence for the utilization of *Musculus*, which are generally more abundant at oiled sites, may help rule out

prey availability as a factor limiting otter or sea duck recovery.

PROJECT DESIGN

A. Objectives

Determine if *Musculus* are utilized a food by either otters or sea ducks, and determine changes to *Musculus* densities that may result from predation by otters or ducks.

B. Methods

No additional field work will be proposed for FY 95 for this task. Instead, we will concentrate our efforts on collating existing observations on the feeding habits of ducks and otters, distribution patterns of ducks and otters, and the distribution of *Musculus* within the Sound. We will examine the possibility that otters and ducks are utilizing *Musculus* by examining observational and (perhaps for ducks) gut contents of the predators. Also, we will assess utilization by overlaying distribution and abundance data for *Musculus* with that for ducks and otters. It is anticipated that we will obtain *Musculus* distribution data as part of the subtidal monitoring program, and that these data will be obtained from areas which cover a range of otter and duck densities. Additional studies (e.g., direct observations of the effects of winter feeding by ducks in eelgrass beds on *Musculus* density) may be proposed for FY 96 if the FY 95 data suggest that *Musculus* are being utilized as food.

C. Schedule

The field work (conducted under separate contract) that will generate data to be used in this task will be largely completed by December 1995. Data analysis and draft report preparation will be completed in May 1996. Deliverables will consist of an FY 95 progress report to be submitted in September 1995, and a final report to be completed by May 1996.

D. Technical Support

No outside technical support will be required.

E. Location

The project will be undertaken in Prince William Sound.

PROJECT IMPLEMENTATION

Principal Investigators for this project have been conducting injury assessment studies in the shallow subtidal within Prince William Sound since 1989, and are submitting several proposals for continued monitoring and assessment of subtidal resources, including *Musculus*. The

investigators involvement in other related projects makes them uniquely qualified to conduct cost effective studies on the interactions among *Musculus* and otters or sea ducks.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is being submitted as an integrated part of proposals dealing with the nearshore ecosystem. It is anticipated that the studies of *Musculus* will be fully integrated with other studies (e.g., monitoring within eelgrass beds) being proposed by the same investigators, and with proposed sea otter and sea duck investigations. It is anticipated that sea otter and sea duck investigators will make key distribution and feeding observations that will be critical in evaluating the interactions between *Musculus* and its vertebrate predators.

FY 95 BUDGET (\$K)

Personnel	4.8
Travel	0.0
Contractual	0.0
Commodities	0.0
Equipment	0.0
Subtotal	4.8
Gen. Admin.	.7
Total	5.5

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Effects of Predatory Invertebrates on Nearshore Clam Populations in Sea Otter Habitats of Prince William Sound

Project Number:	95025H
Restoration Category:	Research (new)
Proposed By:	DOI
Cost FY 95:	\$123,400
Cost FY 96:	\$111,550
Total Cost:	Unknown
Duration:	3 years (however, useful results can be obtained in 1 year)
Geographic Area:	Central and western Prince William Sound
Injured Resource/Service:	Sea otter and clam

INTRODUCTION

This project is one component of an integrated ecosystem-scale Program entitled "Processes structuring recovery of injured nearshore vertebrate predators in Prince William Sound" (NVP). The NVP Program will assess predator-prey relationships in order to understand recovery patterns of significant vertebrate predators injured by the *Exxon Valdez* oil spill (EVOS) in Prince William Sound (PWS). The NVP Program will utilize measured characteristics of prey populations as indicators of predator population density. Because of the important effects of sea otters on benthic ecosystems, abundance and dynamics of significant prey should provide information on the recovery status of sea otter populations.

This project examines effects of invertebrate predators (sea stars, snails, crabs) on clams, the primary prey for sea otters in PWS, in an effort to better assess the recovery status of sea otters, and to find explanations for an apparent failure of sea otters in some areas to recover from EVOS. Nearshore clam populations in PWS are a biological resource injured by EVOS. Patterns of recovery of clam populations from the EVOS are unknown. It is possible that damage to clam populations has contributed to the apparent failure of some PWS sea otter populations to recover from EVOS. Dynamics of clam populations often are influenced substantially by patterns of predation by invertebrates such as sea stars, crabs, and snails. This project will examine the hypothesis that high rates of clam consumption by predatory invertebrates are contributing to lack of recovery from EVOS damage in clam and sea otter populations in some portions of PWS.

Although the NVP Program focuses on injured populations of vertebrate predators, this component project will, in addition, provide useful information regarding EVOS damage to subsistence use of clams. Prior to EVOS, clams were an important subsistence food at numerous locations in PWS. EVOS damage has limited subsistence use of clam resources.

This project is most likely to be effective in achieving stated goals if it is pursued over several years. However, limitation of work to FY-95 will provide information of significant value to the EVOS Restoration Program.

NEED FOR THE PROJECT

This component of the NVP Program will contribute to the ability of resource managers to understand if sea otters and clams are recovering from EVOS, and if not why not, and will allow resource managers and decision makers to use ecosystem-scale data to select appropriate restoration options for sea otters and clams in PWS.

This project will address three important issues regarding the restoration of sea otter and nearshore clam populations in PWS:

1. Are injured clam resources recovering? Clam populations are recognized as an injured resource, but recovery trends are unknown. Documentation of patterns of consumption by predatory invertebrates will provide useful information for determination of population growth trends and recovery potential for clams.
2. What factors are constraining injured resources from recovering? Clams are the most important source of nutrition for sea otters in PWS. If patterns of predation by invertebrates are contributing to low productivity in clam populations, sea otters may be suffering a consequent inability to recover effectively from EVOS damage.
3. How do patterns of clam consumption by predatory invertebrates influence subsistence clam resources in certain portions of the PWS region? An improved understanding of predatory invertebrate effects on clam availability will contribute to more judicious management of clam resources for human use during the recovery period.

PROJECT DESIGN

A. Objectives

The NVP Program will use an integrated, rigorously-managed ecosystem approach to understand the recovery status of nearshore vertebrate predators damaged by EVOS. This component project will assess the effects of predatory sea stars, snails, and crabs on clam population dynamics in sea otter habitats influenced by EVOS. We will study predation by invertebrates on both intertidal and nearshore subtidal populations of clams utilized by sea otters.

Our specific research objectives are:

1. Assemble, synthesize, and evaluate available literature and data on patterns of predation on bivalves by predatory invertebrate species known to occur with reasonable abundance in Prince William Sound, both in intertidal habitats and in subtidal habitats within the foraging range of sea otters.
2. Determine the diets of potentially important invertebrates in nearshore habitats of PWS. Initially, efforts will focus on the following species or taxa known to consume bivalves in PWS: Sea stars: *Pycnopodia helianthoides*, *Evasterias troschelii*; Crabs: *Telmessus cheiragonus*, *Cancer* spp.; Snails: *Nucella* spp. Predatory species of concern may be added or deleted from the list depending on the results of task 1 (above) and early phases of field work. Dietary data will include species composition, numbers or biomass of individuals consumed, and size distribution of individuals consumed. Dietary data will be gathered in the intertidal zone and at two subtidal depths, 6 m and 12 m, in NVP Program study sites.
3. Determine activity-time budgets of predatory invertebrates that forage on bivalves in PWS. Activity data will be integrated with dietary data (task 2 above) to estimate prey consumption rate for each species of predator.
4. Determine patterns of density for predatory invertebrates. Data from tasks 2 and 3 will be integrated with results to provide an estimate of size specific mortality rate of clam populations as a result of predation by invertebrates.
5. If feasible, determine by experimental removal the effects of predation by invertebrates on mortality, population density, and size structure of clam populations. Execution of this task will be contingent on identification of predator species with significant rates of predation, and of clam species with rates of recruitment sufficiently high that a meaningful result is plausible for the experiment.

B. Methods

Numbered sections below are keyed to task numbers shown previously:

1. This work will be done primarily by library database searches and consultation with present and past participants in EVOS Damage Assessment, General Restoration, Research and Monitoring, Habitat Protection, and related activities.
2. Samples will be gathered at three sites in study areas to be selected for the NVP Program beginning in summer 1995. Tentative study areas are north Knight Island/Naked Island, South Knight Island, and Green Island/Montague Island. Samples will be gathered at three depths (intertidal, 6 m, and 12 m). Data will be collected by direct observation during low tide or SCUBA dives (all species), and where necessary will be supplemented by examination of stomach contents.

3. Individuals will be observed and scored for activity type during samples placed by stratified random assignment through the 24-hour cycle in each of the three study areas. Intertidal organisms will be observed directly at low tide or using SCUBA gear if necessary. Subtidal species will be observed during SCUBA dives.
4. Densities of predatory invertebrates will be assessed at three sites within the three study areas on a quarterly schedule beginning in summer 1995. Techniques will vary with species depending on distributional characteristics, activity, and visibility. In most cases sampling will be done by counts in randomly-placed plots or belt transects. Intertidal species will be surveyed during low tide, subtidal species with SCUBA dives.
5. Individuals of the species selected for removal will be gathered during low tide or SCUBA dive on a quarterly basis and transported alive to a distant location to be released unharmed. Clam populations at removal and control sites (minimum of two each) will be sampled by digging and screening (intertidal populations) or by suction dredging (subtidal populations) in randomly-placed plots within the study sites. Predator removals will begin in summer 1995.

C. Schedule

Annual reports will be submitted each year in September. The final report for the project will be submitted in September 1997.

Task-specific milestones:

- Task 1:** Compilation of information will be completed by 1 December 1995. Information will be incorporated in technical reports and publications that result from this project.
- Task 2:** Field samples will be gathered quarterly beginning in summer 1995 and concluding in fall 1996. A technical manuscript will be completed and submitted for publication by 30 September 1997.
- Task 3:** Same schedule as task 2, above.
- Task 4:** Same schedule as task 2, above.
- Task 5:** If found to be feasible, removals will be done quarterly, beginning in summer 1995 and concluding in fall 1996. Samples of clam density will be done quarterly from fall 1995 through fall 1996. A technical manuscript will be completed and submitted for publication by 30 September 1997.

Technical support for each task will be managed through the Washington Cooperative Fish and Wildlife Research Unit (WACFWRU) and the University of Washington (UW).

Field work for the project will be done at study sites in western and central Prince William Sound, Alaska, as specified above for task 2. Laboratory work, data analyses, and production of reports will be done primarily at WACFWRU and UW.

PROJECT IMPLEMENTATION

The NVP Program will be implemented through the National Biological Survey, Alaska Research Center, Anchorage, Alaska. This component project will be implemented through WACFWRU.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The NVP Program, of which our project is part, will establish and maintain a system for integrating component projects, and for integrating NVP projects with other components of the EVOS Restoration Program. NVP will include a Program Coordinator to oversee the compatibility and complementarity of component projects, ensure that milestones are met and deliverables produced, and serve as liaison with other components of the EVOS Restoration Program. In addition, NVP will include a Program Data Manager to oversee database management, facilitate the reasonable exchange of Program data among component projects and to other elements of the EVOS Restoration Program, arrange research travel and charters for NVP investigators, and support the administrative needs of the Program Coordinator. The Program Data Manager will maintain a central repository of all biological data collected by NVP Program participants.

NVP Program participants have established near-term milestones for the development of effective Program integration and management. The milestones are reviewed in the NVP umbrella proposal document.

FY 95 BUDGET (\$K)

Personnel	4.9
Travel	12.5
Contractual	60.5
Commodities	12.5
Equipment	28.0
Subtotal	118.4
Gen. Admin.	5.0
Total	123.4

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Hydrocarbon Monitoring: Integration of Microbial and Chemical Sediment Data

Project Number:	95026
Restoration Category:	Monitoring (new)
Proposed By:	ADEC; Institute of Arctic Biology, UAF
Lead Trustee Agency:	ADEC
Cooperating Agency:	NOAA
Cost FY 95:	\$146,900
Cost FY 96:	\$4,700
Total Cost:	\$151,600
Duration:	2 years
Geographic Area:	There is no field work for this project
Injured Resource/Service:	Intertidal and subtidal organisms and all other injured resources and services dependent upon natural recovery

INTRODUCTION

Biodegradation of hydrocarbons by microorganisms is a major mechanism for removal of petroleum contaminants from marine systems. Since the *Exxon Valdez* oil spill in 1989 we have amassed a great deal of data on microbial numbers and activities in sediments. These studies are unique in the extent of information collected following a major spill and the results provide valuable information on marine sediment microbial responses to hydrocarbon pollutants. For example, numbers of hydrocarbon oxidizers appear to be a good indicator of exposure of sediments to hydrocarbons. Some of these results have been recently accepted for publication in the journal, Marine Pollution Bulletin.

We originally designed our assays, in particular the microbial activity measurements, to stand on their own as much as possible. In other words we wanted some measure that would provide useful site-to-site comparison information without being reliant directly on chemistry data. We feel that we were successful in this goal. However, a great deal of predictive power is lost by not combining our results with sediment chemistry data. An analysis of these combined data sets will allow estimates of removal rates of hydrocarbons from contaminated sediments by biological processes. This will help determine the natural rate of recovery of oiled sediments.

The Trustee Council has previously funded sediment analyses to determine whether intertidal and subtidal sediments are contaminated with oil, and to assess the concentrations and rate of degradation of the oil in these sediments. Microbial activity data can be used in concert with the hydrocarbon chemistry data to calculate the absolute *in vitro* rates of mineralization of the fractions assayed (hexadecane, phenanthrene and naphthalene) in these sediments. Rate data can then be used in turn to estimate persistence of these fractions in sediments in Prince William Sound. In fact the major criticism of our damage assessment final report by the Trustee-appointed peer reviewer was that the microbiology and chemistry data need to be combined so that field rate calculations can be estimated. We wholeheartedly agree with the peer reviewer that these data should be combined both to validate the mineralization assays and to allow predictions of persistence of these hydrocarbons in the environment.

The microbial and sediment chemistry field work was coordinated so that samples for both were collected at the same time in a similar manner. The sampling scheme was designed so that the chemistry and microbiology data could be integrated at some later date. Now that most of the hydrocarbon data is available, combining the data will yield valuable information on the rates of biodegradation of petroleum in contaminated sediments. The two data sets are quite large and the resources have not yet been available to combine them. Synthesis of the data is a large undertaking, but was the major peer-review recommendation for the ST001B final report on microbial activity. The proposed project would fund analysis of some necessary archival hydrocarbon samples and a researcher to complete that synthesis.

Synthesis of the intertidal and subtidal data on the microbial response to oil pollution, with the sediment chemistry data would:

1. Allow the estimation of field rates of biodegradation for hydrocarbon fractions in areas previously monitored for sediment contamination and microbial activity.
2. Establish upper and lower estimates of the persistence of these hydrocarbons in the sediments of the spill area to help establish a rate of recovery of oiled sediments.
3. Refine the tool of using relatively inexpensive microbial analyses as predictors of oil residue in sediments for future use in *Exxon Valdez* hydrocarbon monitoring and for future spills.
4. Comply with the peer-reviewer's recommendation that microbiology and chemistry data be synthesized.

We have two tremendous resources with the chemistry and microbiology data sets. A great deal of critical information about the relationship between numbers of oil degraders and oil concentrations and about the persistence of various fractions of oil in the environment will be lost if this analysis is not done.

This project is important for sediments, and intertidal and subtidal organisms. In addition, while oil itself is not an injured resource or service, it is the cause of the injuries. Monitoring the continued presence of surface oil in the environment including location, concentration, and degradation provides current information and predictions about remaining oil contamination in the ecosystem.

Assessing the location, concentration, and degradation of *Exxon Valdez* oil has been an important activity since the spill. Several microbial degradation projects were funded as part of the Natural Resource Damage Assessment and as part of the oil spill response. In addition to these data sets, the Trustee Council funded sediment and microbial projects in 1992, 1993 and 1994.

NEED FOR THE PROJECT

By using the actual hydrocarbon concentrations provided by the chemistry data, we can make predictions about the actual field rates of oil degradation, and use those values to predict the persistence of oil fractions and the natural rate of recovery of spill area sediments.

This information would help the Council meet the restoration objectives in the following manner:

1. The Council's recovery objective for residual oil contamination of sediments is "...recovery has been achieved when remaining oil concentrations are reduced to a level comparable to pre-spill levels." Since biodegradation is one of the major natural mechanisms for removal of oil from contaminated sediments, this technique will help predict when that occurs.
2. Information on the rates of decomposition and persistence of oil is important foundation information for research involving any injured resource or service that exists in the nearshore environment.
3. It would bring previous Council-funded activities to the close recommended by Trustee Council peer reviewers.

PROJECT DESIGN

A. Objectives

As discussed previously, the study would have the following objectives:

1. Allow the estimation of rates of biodegradation for hydrocarbon fractions in areas previously monitored for sediment contamination and microbial activity.
2. Establish upper and lower estimates of the persistence of these hydrocarbons in the sediments of the spill area to help establish a rate of recovery of oiled sediment.
3. Refine the tool of using microbial analyses as predictors of oil residue in sediments for future use in *Exxon Valdez* hydrocarbon monitoring and for future spills.
4. Comply with the peer-reviewer's recommendation that microbiology and chemistry data be synthesized.

A further objective of this study will be to produce a manuscript from these results for publication in a peer reviewed journal. This publication is important in the transfer of lessons learned from the *Exxon Valdez* spill to the broader community of scientists, regulators and decision-makers. The information gained from this study will be very valuable to decision-makers in future oil spills.

B. Methods

All of the post-spill sediment microbiology data available was collected by personnel associated with our laboratory. This extensive data set (from 6 cruises) has already been included in LOTUS 1-2-3 spread sheets. Corresponding sediment chemistry samples were collected at the same time as sediment for microbial analysis by personnel from the NOAA Auke Bay Laboratory. Some of these samples have been analyzed for hydrocarbons and some have been archived. To achieve the objectives of this proposal we will obtain the existing chemistry data and merge this data with our existing microbiology data. In addition we will need to have approximately 35 archived samples analyzed (three replicates per sample) to provide us with sufficient data. We will query the data base to look for relationships in the data. Our objectives are to use the data to estimate persistence of alkanes and PAH in sediments and to assess the usefulness of microbial techniques for screening samples for chemical analysis. Statistical techniques will be used to determine the robustness of trends observed. We will then use the reduced data as the basis for a final report and at least one journal article. These publications are very important for information transfer. It is expected that we would first focus on data from Prince William Sound.

C. Schedule

Assuming a start date of November 1994, we would complete a draft report by July 1995 and a final report in October 1995. If funding is not received by November 1994 these dates will need to be adjusted to reflect the actual start date.

D. Technical Support

Access will be needed to the microbial and sediment chemistry data. Support will be provided by those most knowledgeable with the sediment chemistry and microbial data sets. These include ADEC and NOAA personnel (for the sediment chemistry), and Dr. Joan Braddock, for the microbial data.

E. Location

With the exception of one trip to Juneau to coordinate with the Auke Bay Laboratory for chemistry data, the project will be located at the Institute of Arctic Biology at the University of Alaska-Fairbanks.

PROJECT IMPLEMENTATION

Significant involvement is required by the Institute of Arctic Biology, University of Alaska-Fairbanks, as well as Trustee Agency personnel who worked with the sediment chemistry. The most cost-effective way to meet the project objectives is through a research associate who will work closely with Dr. Braddock. Dr. Bret Luick has agreed to do this work. Dr. Luick will bring to the project a broad background in chemistry, biology and in data reduction and manipulation.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The focus of this project is to integrate the results from two previous projects-- sediment microbiology and sediment chemistry. Representatives of Trustee agencies that are knowledgeable about the data and who will use the results will be integrated into the process.

FY 95 BUDGET (\$K)

Personnel	48.9
Travel	0.0
Contractual	80.9
Commodities	4.0
Equipment	0.0
Subtotal	133.9
Gen. Admin.	13.0
Total	146.9

Kodiak Archipelago Shoreline Assessment: Monitoring Surface and Subsurface Oil

Project Number:	95027
Restoration Category:	Monitoring (new)
Proposed By:	ADEC
Cooperating Agencies:	All other Trustee Agencies
Cost FY 95:	\$447,800
Cost FY 96:	\$110,800
Total Cost:	\$558,600
Duration:	2 years (field work will be completed in FY 95; some hydrocarbon analyses and the final report will be done in FY 96)
Geographic Area:	Kodiak Archipelago
Injured Resource/Service:	Subsistence, recreation, intertidal and subtidal organisms, all other injured resources and services dependent upon recovery of oiled beaches

INTRODUCTION

This project will determine the areal extent, toxicity and origin of surface and subsurface oil on selected Kodiak Archipelago shorelines. Most of these shorelines were last surveyed in 1990. The information about the remaining oil is necessary to determine whether recovery is proceeding at an acceptable rate; to determine whether winter storms have brought subsurface oil to the surface; to help local people assess whether the presence of remaining oil is still affecting shoreline activities; to determine the origin and toxicity of any remaining oil; and to determine if any beaches need additional treatment.

This project may be the last comprehensive shoreline assessment of the Kodiak area, though it may locate additional "hot spots" that need continued monitoring or treatment. Based upon information from the communities and previous surveys, approximately 100 beach segments will be chosen as representative of oiling conditions in the Kodiak area. If the survey finds more oil than anticipated, additional survey work at additional sites may be necessary in FY 96.

This project is important for subsistence, recreation, sediments, mussels, and intertidal and subtidal organisms. It is also relevant to harlequin ducks, sea otters, and other injured species that feed in the intertidal area. In addition, while oil itself is not an injured resource or service, it is the cause of the injuries. Monitoring the continued presence of oil in the environment including location, extent, origin, and toxicity provides current information about the remaining oil contamination in the ecosystem.

Assessing the amount and location of *Exxon Valdez* oil has been an important activity since the moment of the spill. From 1989 through 1992 extensive shoreline assessment surveys were funded as part of response activities in various parts of the spill area. In 1993 and 1994, the Trustee Council funded two projects:

<u>Project Number</u>	<u>Project Title</u>	<u>Amount Budgeted</u>	<u>Amount Spent</u>
93038	Shoreline Assessment	\$539,200	\$353,000
94266	Shoreline Assessment & Oil Removal	\$365,000	Unknown

- *Prince William Sound.* Limited shoreline surveys and clean-up work occurred in 1991, 1992, and 1993. In 1994, treatment of surface oil and mussel beds was authorized.
- *Kodiak Archipelago, Alaska Peninsula, Cook Inlet, and Outer Kenai Coast.* Since 1990 no sites have been surveyed by the Department of Environmental Conservation on Kodiak or the Alaska Peninsula, and only limited general assessment work has been completed in Cook Inlet and the Kenai Coast. Six study sites were established by the National Park Service in 1992 along national park coast lines. Those sites will be revisited in 1994 by the National Biological Survey.

NEED FOR THE PROJECT

Subsistence. The objective for subsistence restoration adopted by the Trustee Council reads in part, "Subsistence will have recovered when...people are confident that the resources are safe to eat."

In 1993, representatives of the Trustee Council held 22 public meetings throughout the spill area, including nine in the project area. At almost every meeting, residents indicated that they believe the oil remains and it is contaminating their subsistence foods. Based on previous assessments, agency scientists expected that oil would have mostly disappeared from Kodiak and Alaska Peninsula shorelines by now. Information from the public indicates that expectation may be optimistic. Since there has been no shoreline assessment since 1990 to confirm or contradict these beliefs, one is needed now to supply information necessary for restoration efforts. If oil is not found, a believable assessment of that fact in the Kodiak area will be an important step toward restoring confidence in subsistence resources. If oil is found, it will be important for allowing residents to make their own assessment of the safety and reliability of the resources, and to determine if additional beach treatment is warranted. Determining the absence of oil is at least as important as determining the presence of oil.

Some examples from the 1993 Kodiak village meetings illustrate the concern.

"There's many people in our community still afraid to eat subsistence foods. My uncle found a tar ball just the other day. That stuff is still around and it affects our kelp beds, clams beds, and our mussels." (Ouzinkie public meeting, April 1993)

"...I know a lot of people in the room who are still injured. They won't eat the seafood because they don't trust it." (Larsen Bay public meeting, April 1993)

"All these studies you've done are in Prince William Sound...you're going to tell us they apply here too? When they first did testing in 1989 and the first part of 1990, they sent out brochures but we haven't heard anything here since then..." (Larsen Bay public meeting, April 1993)

Recreation. Recreation, like subsistence, is affected by the visual recognition of oil. The objective for recreation restoration adopted by the Trustee Council reads in part, "Recreation and tourism will have recovered, in large part, when the fish and wildlife resources on which they depend have recovered, [and] *when recreation use of oiled beaches is no longer impaired...*" Monitoring the presence or absence of oil is an important part of monitoring the ability of the Kodiak shorelines to provide for recreational and tourism use.

Sediments, mussels, intertidal and subtidal organisms, and other natural resources. Shorelines treated in 1989 and 1990 and other potentially oiled sites need to be evaluated to determine if the shorelines responded to treatment, or if additional localized treatment is required to restore resources and services. Previous surveys in the spill area have shown that surface oil (usually in the form of tar mats) is quite stable, but responds well to treatment. Surveys in Prince William Sound indicate subsurface oil is disappearing at most sites, but some sites would benefit from additional treatment. We have only limited information on the subsurface oil in the Kodiak area, but it may be persisting in some locations. The oil around Kodiak is present primarily in the form of mousse which has been resistant to degradation in Prince William Sound. The resources most affected are sediments, mussels, and intertidal and subtidal organisms. Monitoring the shorelines provides current information that helps scientists understand the recovery of these and other resources and services in the Kodiak area.

PROJECT DESIGN

A. Objectives

1. Provide current information about the presence or absence of oil that is useful for all injured resources and services; that is, the project will update the 1990 information base necessary for other research and restoration in the Kodiak area.
2. Create a common understanding that does not now exist among the Trustees, local residents, subsistence and recreation user groups, scientists, and the general public about the presence or absence of *Exxon Valdez* oil.

3. Where (and if) surface and subsurface oil is found, the project will locate "hot spots" where continued monitoring, and possibly treatment, is necessary. Where oil is found, analysis will be done to determine toxicity and origin of the oil. Where oil is *not* found or found only in trace amounts, the project will end the need for continued shoreline assessments. Thus, this project may be the last comprehensive shoreline assessment project for this area.
4. Maintain (and possibly end) the record of the extent, concentration, and degradation of surface and subsurface oil from the 1989 *Exxon Valdez* oil spill in these areas.

B. Methods

1. Identify shorelines for survey.
Agency component. The Alaska Department of Environmental Conservation, in conjunction with the other Trustee Agencies and in consultation with the U.S. Coast Guard, will review the 1990 shoreline survey and other information and produce a draft list of shorelines to be surveyed in 1995. For planning purposes, we have assumed that about 100 sites will be surveyed.

Community component. Representatives of the Trustee Agencies will work with community organizations and landowners to identify sites where community residents believe that oil is present, and to identify important subsistence or recreation shorelines where it is important to know whether or not oil is present. To avoid deluging communities with independent visits from representatives of various projects, community work will be coordinated with other restoration work. For that reason, the exact method of community interaction cannot be determined until the 1995 Work Plan is approved. However, it will require at least one visit to most communities to identify areas to be surveyed.
2. Survey identified shorelines. Agency technical experts, upland owners, and representatives of local communities will together assess the shoreline segments and document oiling conditions. Three to four person teams will carry out the actual survey work. At least one person on each team will be recruited from the local communities. The same survey techniques used in prior years will be used again to ensure comparability of data from year to year. (See the 1993 Shoreline Assessment Report, Project 93038, for more detail on survey techniques.) Approximately 50 hydrocarbon samples will be collected and analyzed to determine the toxicity and source of the oil.

The survey team will use various methods of transport depending on the location of the survey sites: A Fish and Game vessel will be used for part of June and August, charter vessels may be used some cases, and personnel may stay in communities and use daily boat, plane or helicopter access. Previous *Exxon Valdez* surveys have used all of these methods in the past and found them to be both cost effective and time efficient support structures.

3. As usual, a final report and database will provide the scientific record of the project. The results will be used to plan future activities as appropriate. In addition, each community will be made aware of the results pertaining to their use areas, as well as to the entire shoreline assessment. Final methods of conveying the information have not been determined but they may include community visits, meetings, or special community-specific publications. Information dissemination will be coordinated with the Executive Director's Office and other projects to ensure maximum benefit.

C. Schedule

December - March 1995

Initial identification of shoreline segments (agency component). Submit requests for vessel and float plane charter. Solicit professional services to accompany shoreline assessment team (See Section E: Project Implementation).

April and May 1995

Review shoreline segments (agency component), and identify segments (community component). Produce final shoreline list. Receive approvals from landowners and resource agencies to access shorelines for survey activities.

May through early September 1995

Perform survey

October 1995 through April 1996

Analyze samples to determine toxicity and source of the oil. Complete report and documentation; hold community meetings or perform other method of community outreach to distribute results to the community.

D. Technical Support

The project will require technical support for the following tasks: data processing support to update existing files detailing the conditions of the specific beach segments surveyed; mapping and GIS information concerning the beach segments; database manipulation to identify beach segments and categorize results; geomorphological support to gather and interpret beach geomorphology; lab work for analyzing oil samples; and chemistry support to interpret the results.

E. Location

The Kodiak Archipelago area.

PROJECT IMPLEMENTATION

The location and assessment of hazardous wastes and oil pollution is a basic statutory responsibility of the Alaska Department of Environmental Conservation. ADEC has maintained the state lead in discharging these responsibilities since the day of the spill. In addition, working with local communities to develop trust in the conclusions regarding the safety and condition of their resources is a public responsibility. For these reasons, and to maintain consistency with previous shoreline assessments, control over the decisions and judgements regarding the shoreline assessment, and contact with communities will remain with the Alaska Department of Conservation in cooperation with other Trustee Agencies. However, specific professional and technical portions of the project will be contracted including portions where the expertise is not available within the agency, or in some cases where competition may result in decreased costs. Some survey team members will be recruited from the local communities.

Specifically, the project manager and beach survey crew leaders will be ADEC or other trustee agency employees. At least one member of each survey team will be a short term DEC employee hired from the local communities near the survey sites. A professional services contract will be sought for geomorphological expertise to help the survey crews identify and assess beach segments. Technical contracts will be sought for technical projects needs such as vessel charters and aircraft logistics.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Until other projects in the area are identified, it is not possible to describe exactly how this project will coordinate with them. Every effort will be made to coordinate logistics with other projects. The project will maintain and update a database and knowledge of oiling that provides fundamental baseline data for investigations of the problems with injured resources and services in the Kodiak area. The Methods section describes how the project's methods and locations will be coordinated with the needs of resource agencies, landowners, and local communities. Some sharing of information and logistics may be possible with Project 95090, Oiled Mussel Bed Monitoring.

FY 95 BUDGET (\$K)

Personnel	179.2
Travel	28.2
Contractual	152.4
Commodities	30.5
Equipment	20.0
Subtotal	410.3
Gen. Admin.	37.5
Total	447.8

Population Survey of Bald Eagles in Prince William Sound, Alaska

Project Number:	95029
Restoration Category:	Monitoring (new)
Proposed By:	DOI
Cost FY 95:	\$48,700 (includes data analysis and report writing costs)
Cost FY 96:	\$0
Total Cost:	\$48,700
Duration:	1 year (survey may be repeated in 2000)
Geographic Area:	Prince William Sound
Injured Resource/Service:	Bald eagle

INTRODUCTION

Bald eagles were directly impacted by the *Exxon Valdez* Oil Spill (EVOS). Productivity of PWS bald eagles was greatly reduced during the breeding season following the spill, but returned to normal levels the next year. Population surveys did not indicate any significant difference in eagle numbers among surveys conducted in 1982 prior to the spill and in 1989-91 after the spill. Populations of herring, pink salmon and marine invertebrates, however, were also impacted by the spill and have not recovered. These species are key prey for bald eagles, and reductions in their availability to bald eagles may be adversely impacting eagle productivity and numbers. Populations of other small forage fishes that have not been studied (sand lance, eulachon, etc.) may also have been reduced by the spill, further reducing prey available to eagles. This project will re-survey the population of bald eagles in Prince William Sound (PWS) and compare the 1995 population with populations in prior years to determine if reductions in prey availability have reduced the number of eagles in PWS. The Trustees funded identical population surveys in 1989-91.

NEED FOR THE PROJECT

Bald eagles were studied intensively for two years following the spill and at a reduced level for a third year (1991). Impacts to eagle prey were not evident until after work on eagles was concluded. Eagles are slow to mature and have a long life span. We believe that eagles in Alaska may not enter the breeding population until they are at least 6-8 years old, and eagles are known to live up to at least 28 years. The young that should have been produced in 1989

would just be maturing and few would be entering the breeding population this soon. However, a reduction in numbers of breeding adults would be cause for concern. Loss of breeding adults erodes future productivity potential and exacerbates the effects of reduced productivity. Such losses would require a decade or more for recovery once the debilitating factors were corrected. This survey will help to confirm the recovery of bald eagles and alleviate concern created by the suspected reduction in prey availability.

PROJECT DESIGN

A. Objectives

1. Determine bald eagle population size in PWS in 1995.
2. Compare the 1995 population with populations in 1982 and 1989-91.
3. Confirm that the population is following the increasing trajectory modeled based on previous survey data.

B. Method

Stratified random plots will be flown by fixed wing aircraft using standard survey protocol. Island shorelines within the study area will be censused. The area, plots and shorelines surveyed and censused will be the same as in 1989-91. Differences between years will be compared using a T-test.

C. Schedule

The survey will be flown in early May, 1995. A final survey report will be completed by December 31, 1995.

D. Technical Support

None required.

E. Location

The survey will be conducted in Prince William Sound, based from Cordova.

PROJECT IMPLEMENTATION

The most appropriate entity to implement this project is the U. S. Fish and Wildlife Service. The Service has specific management authority for bald eagles under the Bald Eagle Protection Act of 1940, as amended. The Service conducted the previous surveys on PWS eagles immediately after the spill and has the technical ability, logistic capability and specific field experience to conduct the study.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Data collected during the population survey will supplement the proposed productivity surveys for bald eagles. Data may corroborate findings of studies on prey species and will contribute to an understanding of ecosystem changes in Prince William Sound.

FY 95 BUDGET (\$K)

Personnel	16.0
Travel	5.5
Contractual	18.0
Commodities	5.5
Equipment	0.0
Subtotal	45.0
Gen. Admin.	3.7
Total	48.7

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Productivity Survey of Bald Eagles in Prince William Sound, Alaska

Project Number: 95030

Restoration Category: Monitoring (new)

Proposed By: DOI

Cost FY 95: \$81,900 (includes data analysis and report writing costs)

Cost FY 96: \$0

Total Cost: \$81,900

Duration: 1 year (survey may be repeated in 2000)

Geographic Area: Prince William Sound

Injured Resource/Service: Bald eagle

INTRODUCTION

Bald eagles were directly impacted by the *Exxon Valdez* Oil Spill (EVOS). Productivity of Prince William Sound (PWS) bald eagles was greatly reduced during the breeding season following the spill, but returned to normal levels the next year. Populations of herring, pink salmon and marine invertebrates, however, were also impacted by the spill and have not recovered. These species are key prey for bald eagles and reductions in their availability to bald eagles may be adversely impacting eagle productivity. Populations of other small forage fishes that have not been studied (sand lance, eulachon, etc.) may also have been reduced by the spill, further reducing prey available to eagles. This project would re-survey nest occupancy and productivity of bald eagles in PWS and contrast the results with productivity parameters found to be "normal" in studies of coastal Alaska eagle populations. The Trustees funded identical productivity surveys in 1989-91.

NEED FOR THE PROJECT

Bald eagles were studied intensively for two years following the spill and at a reduced level for a third year (1991). Impacts to eagle prey were not evident until after work on eagles was concluded. Low prey availability would likely be manifested in poor productivity. Bald eagle populations are resistant to the effects of short term low productivity. Continued low productivity, however, will eventually result in the long term reduction of bald eagle numbers. A productivity survey will determine the current level of productivity. This information is necessary to evaluate whether bald eagle populations injured by the spill are recovering as predicted based on population modeling.

PROJECT DESIGN

A. Objectives

1. Determine bald eagle productivity in PWS in 1995.
2. Compare 1995 and 1990 productivity in PWS with productivity in other coastal Alaska populations.
3. Determine whether productivity is within normal bounds.

B. Methods

Standard nest productivity protocol will be followed. Nests within the survey area will be located by helicopter in mid May and nest occupancy will be recorded. The area will be re-surveyed in the third week of July to determine the number of successful nests, the number of young produced and the age distribution of the young. These data will be compared with the same data from PWS in 1990 and from survey results from southeastern Alaska to determine if they fall within the expected range of nest occupancy and productivity for healthy coastal Alaska bald eagle populations.

C. Schedule

The initial survey will be flown in mid May, 1995, and the second survey will be flown in the third week of July. A final survey report will be completed by December 31, 1995.

D. Technical Support

None required.

E. Location

The survey will be conducted in Prince William Sound, based from Cordova, Alaska..

PROJECT IMPLEMENTATION

The most appropriate entity to implement the project is the U. S. Fish and Wildlife Service. The Service has specific management authority for bald eagles under the Bald Eagle Protection Act of 1940, as amended. The Service conducted the previous surveys on PWS eagles immediately after the spill and has the technical ability, logistic capability and specific field experience to conduct the study.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Data collected by this project may corroborate findings of studies on prey species of bald eagles and will contribute to understanding of ecosystem changes in Prince William Sound.

FY 95 BUDGET (\$K)

Personnel	15.0
Travel	8.5
Contractual	52.0
Commodities	0.5
Equipment	0.0
Subtotal	76.0
Gen. Admin.	5.9
Total	81.9

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Reproductive Success as a Factor Affecting Recovery of Marbled Murrelets in Prince William Sound, Alaska

Project Number:	95031
Restoration Category:	Research (new)
Proposed By:	DOI
Cost FY 95:	\$444,800 (includes data analysis and report writing costs)
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	3 years (useful results can be obtained in 1 year; 3-year project is recommended to assess interannual variation in murrelet reproduction relative to forage fish availability)
Geographic Area:	Prince William Sound
Injured Resource/Service:	Marbled murrelet

INTRODUCTION

Marbled murrelets (*Brachyramphus marmoratus*) are the most abundant seabird in Prince William Sound (PWS) in the summer, and their population has declined significantly since the early 1970's. Although murrelets suffered high mortality in the *Exxon Valdez* oil spill, the spill cannot account for the 65% reduction in numbers observed in post-spill years. There has been no significant increase in the PWS murrelet population since 1989. The goal of this project is to determine if low reproductive success is limiting the recovery of marbled murrelets in Prince William Sound, and if so, if food limitation or predation are responsible. This project is a continuation of previous restoration studies funded by the Trustee Council, wherein nesting habitat and foraging patterns of murrelets were investigated.

NEED FOR THE PROJECT

In other areas of its range, marbled murrelet populations have declined primarily due to the loss of old-growth forest nesting habitat. However, a comparatively small proportion of potential nesting habitat has been harvested in PWS. Concurrent with murrelet population declines, populations of other apex predators that eat small schooling fish have also declined in PWS. During the breeding season murrelets depend on forage fish such as sand lance, capelin, juvenile herring and juvenile pollock. Thus, one explanation for the decline of the PWS

murrelet population is that food is limiting recovery by affecting murrelet reproductive success.

Murrelet reproduction may be limited by food if adults can not provide sufficient quantity or quality of prey to their chicks. Additionally, nest habitat or adult foraging patterns may affect the vulnerability of chicks to predation. Depredation has been a common source of nest failure for the few murrelet nests in PWS that have been monitored. This project is a multi-year study with the overall objective to determine if food availability or predation is limiting the recovery of the PWS murrelet population. This hypothesis will be investigated by comparing annual differences in murrelet reproductive parameters to relative prey abundance in PWS. In 1995 we will determine if there is evidence of food limitation by assessing chick provisioning rates and reproductive success.

This project will use two approaches to monitor murrelet productivity in PWS: i) observations of individual radio-tagged murrelets and their nesting success and ii) at-sea surveys to assess juvenile/adult ratios at selected sites.

If food is a limiting factor, management efforts can be directed at the forage fish population of PWS. As the most abundant apex predator in the PWS marine ecosystem, the murrelet is an important indicator of the health of the marine environment. Furthermore, information on the foraging ecology of the marbled murrelet can contribute to the development of PWS ecosystem trophic models. Our results will compliment studies of forage fish abundance and distribution in relation to oceanographic characteristics.

PROJECT DESIGN

A. Objectives

1. Determine the reproductive success of radio-tagged murrelets and the effects of predation and adult foraging patterns.
2. Determine if predation rates on chicks are influenced by the foraging patterns of the adults.
3. Develop an index of reproductive success by surveying for juveniles at-sea, in the early post-fledging period.

B. Methods

Thirty radio-tagged birds will be used to locate nest sites. Nest status will be determined periodically by observers using night scopes or by video cameras equipped with remote sensors. Number and timing of visits by radio-tagged adults to their chicks will be monitored using Data Collection Computers (DCCs) and hand-held receivers. Prey types and predation of adults on the nest, eggs and chicks will be determined by direct observation or video. Information on the foraging patterns of these radio-tagged adults will be collected by the same researchers contracted to capture and radio-tag the murrelets.

We will continue our efforts to develop an index of reproductive success that can be used to estimate annual murrelet production for a relatively large area. Surveys to determine the distribution and abundance of juvenile murrelets will be conducted from 25 ft. vessels using USFWS protocol. Complete shoreline surveys and randomly selected offshore transect routes will be surveyed in five areas of PWS. June surveys will be conducted to assess the adult population during the incubation phase of murrelet breeding. Follow-up surveys will be conducted at the same locations between late July and mid August, when murrelet fledglings are on the water. The ratio of juveniles to adults will be determined relative to the June adult counts and the late summer adult counts. The absolute number of juveniles will be used to assess variability among areas and years. A better understanding of juvenile dispersal is necessary to interpret at-sea surveys. Dispersal patterns of juveniles will be investigated by marking accessible chicks that are near fledging age with radio tags or dye, and following them after fledging.

We will use non-parametric tests to examine the relationships between reproductive success, predation rates and chick feeding patterns at individual nests, as nest sample size will be small (estimated 10-15 nests). On a larger scale, we will examine the relationship between murrelet productivity and forage fish abundance as determined by the forage fish study. Information on the prey used by murrelets will be provided by the BAA study on food web relationships of PWS. Vegetation and landscape data will be collected by FWS at the murrelet nests to expand the database on nesting habitat.

C. Schedules

Oct-May 1994	Contracting, hiring, procurement
May-Aug	Field work
Sept-Nov	Data analysis
Dec-Jan	Report writing
Jan 1995	Draft Report
March 1995	Final Report

D. Technical Support

This study will require FWS Geographic Information System mapping support. Ancillary prey samples we obtain (fish brought to chicks or otoliths found in chick feces) will require lab analysis.

E. Location

The primary study sites will be areas where murrelets have been successfully captured or are known to nest. These sites may include Eaglek Bay, Unakwik Inlet, Naked Island, Knight Island and Port Nellie Juan. Potential sites may also be selected from areas where other seabird or forage fish studies will be conducted. Because murrelets forage over large areas, the study area will include all of PWS.

PROJECT IMPLEMENTATION

The Migratory Bird Management Division of the U. S. Fish and Wildlife Service has conducted studies on the marbled murrelet in PWS since 1989, and has the technical expertise and logistical support required to complete this project. The FWS has located more murrelet nest sites than any other murrelet project to date. The FWS has trust responsibility for murrelets and all other seabirds as designated in the Migratory Bird Treaty Act of 1918.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is one of several proposals to investigate whether food availability is limiting the recovery of injured species that prey on forage fish. It will share logistical support and data on prey with the pigeon guillemot and kittiwake studies. This study will complement and benefit from other proposed studies: NBS's (puffin diet, PWS food web), NOAA's (forage fish, prey energetics).

FY 95 BUDGET (\$K)

Personnel	224.7
Travel	8.6
Contractual	125.0
Commodities	15.0
Equipment	29.0
Subtotal	402.3
Gen. Admin.	42.5
Total	444.8

Kittiwakes as Indicators of Forage Fish Availability

Project Number:	95033
Restoration Category:	Research (new)
Proposed By:	DOI
Cost FY 95:	\$198,500 (includes data analysis and report writing costs)
Cost FY 96:	\$203,100 (includes data analysis and report writing costs)
Total Cost:	\$819,100
Duration:	5 years, depending on frequency and duration of forage fish project
Geographic Area:	Prince William Sound and Gulf of Alaska
Injured Resource/Service:	Multiple resources

INTRODUCTION

Populations of several species of marine birds and mammals that prey on forage fish have declined in Prince William Sound (PWS) since 1972. Conversely, populations of most species that feed on benthic invertebrates have not declined. Marbled murrelets, pigeon guillemots, arctic terns, black-legged kittiwakes, glaucous-winged gulls and puffins and harbor seals feed on schooling forage fish, and have declined by more than 50%. Harlequin ducks, goldeneyes, black oystercatchers and sea otters feed on benthic invertebrates and have not declined throughout PWS, although some species were affected by the *Exxon Valdez* oil spill. This pattern of fish-eating species declining and benthic invertebrate-eating species not declining suggests that important forage fish populations may have declined in PWS in the past 20 years. There are no population trend data on forage fish in PWS to support or refute this hypothesis.

If fish-eating marine bird and mammal populations that were injured by the *Exxon Valdez* oil spill (i.e., common murre, marbled murrelet, pigeon guillemot, and harbor seal) are limited by food, recovery of these populations is not possible. Therefore, an important question concerning the recovery of these injured species is: Are their populations limited by food? The goal of this study is to evaluate the relative availability of food for kittiwake populations in PWS, which serve as an indicator of other seabird species. This study, in conjunction with the forage fish study, will provide data to answer the question: Is food limiting the recovery of injured species' populations?

The Trustee Council funded a kittiwake damage assessment study in 1989. The study found that reproductive success of kittiwakes was damaged by the oil spill. Prior to and after the spill the U. S. Fish and Wildlife Service (USFWS) monitored kittiwake population size and reproductive success in PWS. The USFWS study demonstrated that reproductive success of kittiwakes in PWS has not recovered since the EVOS and worsened in 1992 and 1993. Data from USFWS monitoring also suggested that food availability to kittiwakes nesting in PWS may have decreased. The USFWS monitoring will continue and the proposed study will complement the monitoring.

NEED FOR THE PROJECT

The common murre, marbled murrelet, pigeon guillemot, and harbor seal are injured species that eat forage fish. A major question concerning the recovery of these injured species is: Are their populations limited by food?

To answer the question of food limitation for seabirds, the best species to study are those that occur throughout PWS, and for which data on foraging and breeding parameters can easily be collected. In PWS, kittiwakes are well suited to address the food limitation question. Several parameters of kittiwake foraging and breeding indicate physiological stress caused by limited food. There are 24 colonies of kittiwakes spread throughout PWS, and because kittiwakes are colonial cliff-nesters their productivity and brood size can be obtained for all colonies fairly easily. Other breeding and feeding parameters are also inexpensive and easy to record. Also, there are ten years of population size and productivity data for kittiwakes in PWS that can be used for comparison.

Because kittiwakes prey on similar forage fish species as marbled murrelets, pigeon guillemots, and murres, they act as indicator species of the availability of prey such as juvenile herring, sand lance, and various osmerids (smelts). However, because kittiwakes are surface feeders, a diving species such as the pigeon guillemot should also be studied.

The USFWS will continue to monitor kittiwake colony size and productivity in PWS. The project proposed here will expand on this basic monitoring by providing reasons for the continuing failure of kittiwakes to reproduce since the EVOS. Information about the availability and distribution of forage fishes in PWS generated by this project will also be useful for understanding food web relationships of other bird species that were injured by the EVOS, and the entire PWS ecosystem.

PROJECT DESIGN

A. Objectives

1. Determine relative food availability to kittiwakes by
 - a. Monitoring reproductive parameters, including egg laying date, clutch size, hatching success, growth rates, fledging success, brood size at fledging and overall productivity.
 - b. Monitoring diets and foraging parameters such as: foraging trip length, foraging trip distance, foraging areas, chick provisioning rates, species and size of prey consumed.
 - c. Monitoring survival rates of adults.

B. Methods

Twenty-four kittiwake colonies in PWS and three colonies in the northern Gulf of Alaska will be monitored for productivity and brood size at fledging. Clutch size will be monitored at 10 to 12 colonies in PWS. Hatching success, chick growth rates, fledging success, and diets will be monitored at four to six colonies in PWS. All parameters will be measured at two or three colonies in PWS.

Methods for measuring reproductive parameters and foraging of kittiwakes are described in Irons. All methods have been tried and were successful in one or more other studies on kittiwakes. Productivity will be determined for entire colonies in PWS and study plots at colonies outside PWS. Productivity will be determined by counting the numbers of nests in June and the number of pre-fledging chicks in August and calculating an average number of chicks per nest. Egg laying dates, clutch sizes, hatching success, chick growth rates, provisioning rates and fledging success will be determined for nests in study plots at colonies. Foraging trip length will be measured using radio-tagged birds and data collection computers to monitor their foraging trips. Foraging trip distance and foraging areas will be determined by locating foraging radio-tagged birds with boats and planes in conjunction with the marbled murrelet project.

C. Schedule

October-May	Prepare for field season
June-August	Field work
Sept.-Nov.	Data analysis
Dec.-Jan.	Report Writing
January 1995	Draft Report
March 1995	Final Report

D. Technical Support

This project will require technical support for analysis of diet samples and GIS analysis.

E. Location

Kittiwakes will be monitored throughout Prince William Sound at 24 kittiwake colonies and in the northern Gulf of Alaska at the Wooded, Chiswell and Barren islands in conjunction with the proposed puffin project.

PROJECT IMPLEMENTATION

The U. S. Fish and Wildlife Service is the most appropriate entity to conduct this project. The National Biological Survey will be responsible for the data collection at the Wooded, Chiswell and Barren islands, which will occur in conjunction with the puffin project.

The U.S. Fish and Wildlife Service has the technical expertise to conduct this study. Other similar projects have been conducted by the USFWS on kittiwakes in Prince William Sound for several years. Successful methods have been established to collect and analyze data. The USFWS has trust responsibility for kittiwakes and all other seabirds as designated in the Migratory Bird Treaty Act of 1918.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will collaborate with several other projects that will investigate whether food availability is limiting the recovery of injured species that prey on forage fish. Proposals on this topic will be submitted by several agencies and private groups. The agencies include NOAA, NBS, ADFG, and USFWS. There will also be proposals concerning prey energetics, which was advertised as a NOAA broad agency announcement. This study meshes especially closely with NOAA's forage fish study, NBS's puffin and murre studies, the food web study, with the BAA topic of energetics of prey, and with other FWS studies on murrelets and pigeon guillemots. The forage fish project will provide data on the abundance of forage fish in areas where kittiwakes, puffins, pigeon guillemots and murrelets feed. The energetics study will provide data on the value of various prey species to kittiwakes and other fish eating seabirds. This suite of bird studies along with the forage fish study should be successful in determining if food, predation, oil toxicity or a combination of these factors are limiting the recovery of injured species.

FY 95 BUDGET (\$K)

Personnel	106.9
Travel	6.0
Contractual	19.1
Commodities	15.0
Equipment	34.1
Subtotal	181.1
Gen. Admin.	17.4
Total	198.5

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Symposium on Seabird Restoration

Project Number:	95038
Restoration Category:	General Restoration (new)
Proposed By:	Pacific Seabird Group
Lead Trustee Agency:	DOI
Cost FY 95:	\$74,400
Cost FY 96:	\$10,100
Total Cost:	\$84,500
Duration:	2 years
Geographic Area:	There is no field work for this project
Injured Resource/Service:	Common murre, marbled murrelet, pigeon guillemot, black oystercatcher

INTRODUCTION

The Trustee Council has struggled for the past five years with determining the most efficacious means to restore seabird populations that were damaged by the oil spill. The Pacific Seabird Group (PSG) proposes to host a symposium in Alaska during September or October 1995 to discuss the science of seabird restoration. PSG would invite and sponsor knowledgeable scientists from around the world to discuss the benefits and costs of every technique to restore seabirds that has been used.

The affected seabird species include common murres, marbled murrelets, Kittlitz's murrelets, pigeon guillemots, tufted puffins, cormorants, black oystercatchers, black-legged kittiwakes and ancient murrelets. Some of these species suffered severe losses in the spill, but little work has been done to restore their populations.

NEED FOR THE PROJECT

The symposium will provide state and federal trustees with a realistic approach to the most effective means of restoring Alaska's seabird colonies. PSG has been involved with the EVOS restoration process since the beginning, and we believe this symposium would assist the Trustee Council with seabird restoration.

PROJECT DESIGN**A. Objectives**

1. Identify and evaluate the techniques that can be used to restore seabird populations injured by oil spills.
2. Gather knowledgeable scientists from throughout the world to attend and participate in discussions.

B. Methods

(1) Identify suitable scientists; (2) inquire as to their availability and need for travel funds; (3) develop a symposium format that will concentrate on discussion and practical experiences. Formal paper sessions will be included, but the focus will be on discussions to identify the most efficacious restoration methods; (4) Minutes of the meeting and general conclusions will be available. A synthesis of the discussions and papers could be published, but is not included in this proposal.

C. Schedule

Contract Award	Month 1
Work Begins	Month 1
Scientists identified and invited	Month 3
Planning completed	Month 5
Draft Report	October 1995
Final Report	December 1995

D. Technical Support

None.

E. Location

Kodiak or Anchorage, after discussions with the Trustee Council.

PROJECT IMPLEMENTATION

PSG should undertake this project. PSG is an international organization that was founded in 1972 to promote knowledge, study and conservation of Pacific seabirds. PSG draws its members from the entire Pacific Basin, and includes biologists who have research interests in Pacific seabirds, state and federal officials who manage seabird refuges and individuals with interests in marine conservation. PSG has hosted symposia on the biology and management of virtually every seabird species affected by the *Exxon Valdez* oil spill, and has sponsored

symposia on the effects of the spill on seabirds. PSG is uniquely qualified to implement this project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project can be integrated with all on-going seabird restoration projects.

FY 95 BUDGET (\$K)

Personnel	6.0
Travel	30.0
Contractual	35.0
Commodities	0.0
Equipment	0.0
Subtotal	71.0
Gen. Admin.	3.4
Total	74.4

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Common Murre Productivity Monitoring

Project Number:	95039
Restoration Category:	Monitoring (continuation of 94039)
Proposed By:	DOI
Cost FY 95:	\$154,200 (includes \$30,500 for data analysis and report writing on FY 94 work)
Cost FY 96:	\$33,200
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	East Amatuli Island and East Amatuli Light Rock, Barren Islands
Injured Resource/Service:	Common murre

INTRODUCTION

Common murres (*Uria aalge*) are the injured resource addressed by this project. Both documented and estimated losses of murres were higher than losses suffered by any other avian species following the 24 March 1989 *T/V Exxon Valdez* oil spill. The Barren Islands contained one of the largest nesting concentrations of these diving fish-eating seabirds in the path of the oil.

The proposed FY95 common murre restoration monitoring project focuses on obtaining detailed data on the productivity and nesting chronology of murres in the Barren Islands, a location recently proposed as the key restoration monitoring site for obtaining this information. Implementing the project will provide one year of the multi-year data set required to determine whether common murres are recovering from the *Exxon Valdez* oil spill.

The FY95 work is related to several previous Trustee Council projects including damage assessment studies of common murres during 1989-1991 (Bird Study No. 3; e.g., Nysewander *et al.* 1993), and murre restoration monitoring studies in 1992 (Restoration Project No. 11; Dragoo *et al.* 1993), 1993 (Project 93049, Roseneau *et al.* 1994) and 1994 (Project 94039, currently underway). These projects were designed to collect detailed information on numbers, productivity, and nesting chronology at the injured Barren Islands colonies. The proposed FY95 work is a continuation of the 1993-1994 studies; however, it is specifically designed to monitor only productivity and timing of nesting events. Monitoring of population size will be deferred

until 1996. This approach follows the proposed Recovery Monitoring Strategy formulated during the 13-15 April 1994 workshop.

NEED FOR THE PROJECT

This project is the first part of a potential three to four year-long restoration monitoring program designed to collect additional detailed information on the productivity of injured common murres in the Barren Islands. These productivity data are needed to help determine the recovery status of this injured resource. The FY95 work will provide critical information on numbers of fledged chicks per nest site, timing of nesting events (e.g., egg-laying and hatching dates), and attendance of adults that will be combined with similar data collected during 1993 and 1994. This information will be used in conjunction with at least two (possibly three) more years of data collected during 1996-1997 (possibly 1998) to determine whether reproductive timing and success are within normal ranges, based on prespill data and information from other nesting colonies located outside the spill zone. At least five years of data are required to allow for natural variation.

The draft Recovery Monitoring Strategy suggests that productivity studies for murres should be conducted for four years starting in FY95. However, because detailed productivity information will be available from the FY93 and FY94 studies, two years of work after FY95 will produce a five-year data set that should be sufficient to determine whether production and breeding schedules are within normal ranges for Gulf of Alaska colonies.

Both the injured resource and the public will benefit from the proposed project. Common murres will benefit because 1995 productivity data will help resource managers and the Trustee Council determine whether murres are recovering or whether other measures need to be taken to ensure full recovery of this injured species to pre-spill levels. For example, computer simulation models developed for the Trustee Council that estimate recovery rates for murre populations can utilize the 1995 productivity data to more accurately predict rates of recovery for this injured resource. The general public will benefit because they will have access to new information on the status of the avian species that suffered the greatest known direct mortality from floating oil. Private sector businesses offering sight-seeing and birding tours to the Barren Islands and other Gulf of Alaska colonies will benefit because they will have new information on the status of the injured species that will help them plan trips, prepare lectures, and be of interest to their clientele.

PROJECT DESIGN

A. Objectives

Monitor the recovery of Barren Island murres by collecting data on reproductive timing and success and determining whether these biological variables fall within normal bounds.

B. Methods

This project will collect high quality information for determining whether murre productivity and timing of nesting events are within normal ranges. Funds will be conserved by focusing efforts at East Amatuli Island. Both East Amatuli and Nord islands were included in the 1993 and 1994 studies, but Nord Island is difficult to access, and including Nord Island increases the cost of the study by at least \$60K.¹ In 1993, differences in productivity values and timing of nesting events between murres nesting on East Amatuli and Nord islands were not significant. We therefore proposed to limit monitoring efforts to East Amatuli Island and Light Rock, with the exception of placing time-lapse cameras on Nord Island to collect attendance and chronology data.

The objective of the draft Recovery Monitoring Strategy for common murres is to monitor productivity in the Barren Islands for a few more years to ensure that it remains within normal bounds. Data collected at East Amatuli Island and Light Rock in FY95, when combined with information from 1993-1994 and additional work there in 1996-1997, will produce a five year data set that should be sufficient to meet this goal.

The methods employed during the FY93 and FY94 DOI-FWS Barren Islands common murre restoration studies (Projects 93049 and 94039) will be used to collect FY95 productivity data. These methods are based on standard refuge and seabird colony protocols. Data will be collected from at least 10 productivity plots, including 9 on East Amatuli Island and 1 on Light Rock. These plots, first established in 1993, contain about 250 nest sites and sample a variety of nesting habitats. Data will also be collected from at least two new plots that will be set up on East Amatuli Island during FY94. The new plots, located in a different sector of the colony, will contain about 20-30 nest sites each.

Observations will encompass the time from before eggs are laid until chick-fledging peaks. Each plot will be visited every three to four days, weather permitting, and observations will be made with the aid of high quality binoculars and spotting scopes. Data collected during the visits will provide information on productivity (numbers of eggs laid and hatched and chicks fledged per plot, per pair, and per total number of adults). These data will also be used to determine timing of nesting events (first egg-laying dates, and mean and median laying, hatching, and fledging dates).

¹Camp sites are not available on Nord Island, and crews must camp on nearby Ushagat Island. Because of strong tidal rips and swells backed by westerly winds, the crossing between Ushagat and Nord islands requires, particularly in the late season (August-September), the use of a large, contract vessel.

Information on any factors or events that might adversely affect murre productivity will be collected (e.g., avian predation events, adverse weather conditions, charter boat activities, aircraft overflights). During predation and other disturbance episodes, large numbers of birds often flush from the nesting cliffs. Efforts will be made to quantify both numbers of flushing individuals and numbers of incubating or brooding birds remaining on the nesting ledges during and after these types of events. During flushing events, special care will also be taken to look for falling eggs or chicks.

Two time-lapse cameras will be set up at the East Amatuli Island productivity plots to record attendance of adults during the breeding season. These attendance data will be supplemented with regular counts of adults on the study plots (i.e., counts made during visits to collect productivity data). Two additional cameras will be set up to obtain similar attendance information at the Nord Island productivity plots for comparison with East Amatuli Island data and data collected in previous years.

Because sea surface temperature (SST) can influence timing of nesting events at murre colonies, water temperatures will be taken on a regular basis at several locations near East Amatuli Island with a datalogger device and pre-calibrated hand-held thermometers. Broader-scale breeding season SST data will be obtained via AVHR satellite imagery from the Geophysical Institute at the University of Alaska-Fairbanks for the 1989-1994 breeding seasons. Barren Islands SST information will also be obtained from other sources. All efforts to obtain SST data will be coordinated with principal investigators of other agencies and organizations working on Trustee Council projects (University of Alaska Institute of Marine Science, Prince William Sound Science Center, and NOAA researchers).

When time allows during the productivity study, eight special multi-count plots at East Amatuli Island and Light Rock will be counted several times during appropriate times of day and periods of the nesting cycle (i.e., between 1100-2000 hrs in the late incubation - late chick-rearing period). These small-scale counts, which can be made at no extra cost to the project, will provide a small, but valuable amount of "off-year" information that can be integrated with large-scale population census data that are currently scheduled to be collected every third year beginning in FY96.

C. Schedule

Oct-Dec 94	94039 data analysis
Dec-Jan 95	94039 report writing
Jan-Mar 95	Recruit seasonal employees for '95 field season.
Feb 15 95	94039 draft report due
Mar 31 95	94039 final report
Apr-Jun 95	Field preparations
Jun-Sep 95	Field work
Sep-Dec 95	95039 data analysis
Jan-Mar 96	95039 report writing
Mar 15 96	Submit draft report

D. Technical Support

None. However, some technical support may be required at a later date to help interpret satellite imagery of sea surface temperatures.

E. Location

East Amatuli island in the Barren Islands, about 75 km south-southwest of Homer, between the Kenai Peninsula and the Kodiak Archipelago. The study will be staged from Homer.

PROJECT IMPLEMENTATION

The U.S. Fish and Wildlife Service is the most appropriate entity to implement this project. The Barren Islands are part of the Alaska Maritime National Wildlife Refuge (AMNWR), and the AMNWR office in Homer has an experienced research team that has the technical capabilities needed to successfully carry out this project. The Barren Island murre colonies are particularly dangerous, difficult places to work. Nesting cliffs are located in areas where strong tidal currents and rips develop on a regular basis (1.5-2.5 m-high standing waves and currents exceeding 5-6 kts are common). Productivity plots are only accessible with the aid of boats, and use of running-line mooring systems capable of withstanding 6-9 m seas during storms and technical rock climbing equipment. The proposed project leader and field team leader have the training, experience, and technical knowledge necessary to safely work at remote locations in these situations and conditions. AMNWR staff assigned to this project have a combined total of 12 seasons experience working at these rugged Gulf of Alaska murre colonies and over 40 years combined expertise conducting similar types of seabird studies. This level of knowledge of both the biology of the birds and study area conditions will make it easy to efficiently plan and implement this study.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The FY95 common murre monitoring study is a complete, stand-alone project that is directly related to FY93 and FY 94 Barren Islands murre work. However, it is also part of a larger, integrated ecosystem oriented package of bird and marine mammal restoration projects designed to address the information needs of the Trustee Council. The FY95 work will be coordinated with several studies listed in the package, if they are funded. Projects most likely to produce information relevant to the Barren Islands murre productivity work that have been tentatively selected for coordination efforts include proposed investigations of murre foraging areas, food web relationships, foraging efficiencies at food patches, forage fish assessment, and fisheries oceanography.

The project will also be coordinated with other FWS and National Biological Survey seabird monitoring work in the Gulf of Alaska and elsewhere (e.g., Bering Sea). Data collection and

analysis methods will be reviewed to ensure that data can be compared between studies. Efforts will be made to share personnel and equipment whenever possible.

FY 95 BUDGET (\$K)

Personnel	93.2
Travel	29.2
Contractual	0.0
Commodities	11.0
Equipment	6.8
Subtotal	140.2
Gen. Admin.	14.0
Total	154.2

Introduced Predator Removal from Islands: Follow-up Surveys

Project Number: 95041

Restoration Category: General Restoration (continuation of 94041)

Proposed By: DOI

Cost FY 95: \$66,500 (includes \$20,400 for data analysis and report writing of FY 94 work)

Cost FY 96: \$6,200 (data analysis and report writing only)

Total Cost: \$72,700

Duration: 2 years

Geographic Area: Simeonof and Chernabura islands in the Shumagin Islands, western Gulf of Alaska

Injured Resource/Service: Black oystercatcher, pigeon guillemot, common murre

INTRODUCTION

In 1994, the Trustee Council funded a project (No. 94041) to restore populations of injured black oystercatchers (*Haematopus bachmani*) and pigeon guillemots (*Cephus columba*) by removing introduced arctic foxes (*Alopex lagopus*) from Simeonof and Chernabura islands in the Shumagin group, western Gulf of Alaska. It will be necessary to survey these islands in 1995 to eradicate remaining foxes or to determine that none remain. In addition, surveys of oystercatchers, guillemots and other seabirds will be conducted to determine whether their populations are beginning to increase following fox removal.

NEED FOR THE PROJECT

Few options are available for direct restoration of black oystercatcher and pigeon guillemot populations injured by the oil spill, but it is possible to take action to cause populations to expand at the western edge of the area affected by oil by removing introduced foxes from islands where they have kept numbers of oystercatchers, guillemots, and other populations of seabirds depressed. Fox removal efforts began at Simeonof and Chernabura islands in 1994, and it will be necessary to return to the islands in 1995 to verify that no foxes remain. Following a winter with no foxes present, evidence like lack of fresh tracks and scat, and grown-over fox trails may be used to determine if foxes remain.

PROJECT DESIGN**A. Objectives**

1. Determine that arctic foxes have been eradicated from Simeonof and Chernabura islands.
2. Document increases in black oystercatcher and pigeon guillemot populations at Simeonof and Chernabura islands as a result of elimination of introduced foxes.

B. Methods

Fox Surveys. Crews will check beaches, trails, and creek banks for signs of foxes on Simeonof and Chernabura islands. If it is determined that foxes remain, trapping according to methods used in 1994 will be used to remove remaining foxes.

Oystercatcher and Guillemot Surveys. As in 1994, oystercatchers will be monitored by surveying beaches on foot and from a small inflatable boat operated within 30 m of the shoreline. Guillemots will be counted from a small inflatable boat during nearshore surveys of island perimeters. Surveys will be conducted at Simeonof, Chernabura, and the three control islands surveyed in 1994 (Bird, Atkins, and Herendeen). All surveys would be conducted during the early incubation period of each species. At least 3 surveys will be made of each island to provide a basis for examining variation among counts.

C. Schedule

Oct-Dec 94	94041 data analysis
Dec -Jan 95	94041 report writing
Feb 15, 95	94041 draft report
Mar 95	Complete 95041 study plan, procure equipment, and select temporary field personnel
Mar 31, 95	94041 final report
Apr 95	Continue procurement of equipment and supplies
May 95	Organize and pack supplies, and train field personnel
Jun 95	Establish camps on Simeonof and Chernabura islands to check for signs of foxes and to survey populations of oystercatchers and guillemots at these two islands and the "control" islands (Bird, Atkins, and Herendeen).
Jul 95	Leave Shumagin Islands and return to Homer
Aug 95	Clean and store equipment, begin report
Sep-Oct 95	95041 data analysis and writing draft report
Nov 95	Submit revised 95041 report

D. Technical Support

None required

E. Location

The project will occur in the Shumagin Islands. The nearest community is Sand Point, about 80 miles away.

PROJECT IMPLEMENTATION

The DOI-Fish and Wildlife Service is the most appropriate entity to conduct this project because this is a followup to the project began in 1994. The same people that conducted the 1994 program would be best suited because of their local knowledge of the project sites, experience in evaluating the success of fox removal efforts, knowledge of locations of bird study plots, and familiarity with the 1994 data for comparisons. Furthermore, the restoration sites are on the Alaska Maritime National Wildlife Refuge, and the staff of that agency is in the best position to insure that the information gained is incorporated into the long-term refuge management program.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This is a direct restoration project.

FY 95 BUDGET (\$K)

Personnel	38.0
Travel	12.8
Contractual	0.0
Commodities	5.5
Equipment	4.5
Subtotal	60.8
Gen. Admin.	5.7
Total	66.5

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***In situ* Formation and Ecotoxicity of Hydrocarbon Degradation Products Produced by ultramicrobacteria**

Project Number:	95044
Restoration Category:	Research (new)
Proposed By:	Institute of Marine Science, UAF
Lead Trustee Agency:	NOAA
Cost FY 95:	\$135,100
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

Marine bacteria are abundant throughout the oceans. Their biomass is about equal to that of other organisms in the oceans combined. Abundance and small size gives a large surface area for the collection of organic compounds. These compounds are i) remineralized to support primary productivity, ii) reorganized into new organic compounds, or iii) passed to bacterivores and on up the food chain to an extent that rivals primary productivity by phytoplankton.

Most marine bacteria are poorly understood because they are too small to be seen by conventional microscopes. Adapted to growth in dilute media, they fail to grow on conventional recipes so that focus has been on large but rare forms that are particularly fast-growing in the laboratory. Most measurements of hydrocarbon oxidizing bacterial populations related to the *Exxon Valdez* oil spill include only those which will attain large populations in conventional laboratory culture, while most activity is associated with the smaller forms.

New ways to evaluate the mostly undescribed but more typical marine bacteria include phylogenetics, flow cytometry, and extinction culture. Their growth rates *in situ* can be measured by dilution culture. According to phylogenetics, these oligotrophs may be in either of two kingdoms, the Eubacteria and the Archaea. All other organisms are in the third. Most with Eubacterial DNA belong to members of new and yet undescribed genera. A few of these super-small organisms have now been cultivated. To date none of the Archaea have been isolated. However their 16S rRNA sequences indicate particular importance in extreme

environments such as Antarctica and Prince William Sound where abundances exceed 105 organisms per ml.

Ecosystem function is probably most closely tied to water chemistry. The biomass of marine organisms is clearly controlled by major nutrients, and most of these are liberated from organics by bacteria. Other interspecies interactions and chemically mediated responses may be even more important but more difficult to observe. Ecosystems have been relatively stable over eons at a state far from thermodynamic equilibrium. One explanation of this highly improbable behavior is that organisms learned from their mistakes that harmonious coexistence is preferable to exclusionary competition. This learned behavior is then shared among contemporary species much as strategies for assembling antibiotic resistance mechanisms is shared. Because bacteria are prone to sharing genestocks with dissimilar organisms, they may have additional importance to ecosystem function as mediators of information. This information is used in part to maintain ecosystem balance.

Ecotoxicity of aromatic hydrocarbons is connected to their physical properties. Hydrophobicity drives them into the phospholipid envelopes of bacteria where oxidases therein cleave the rings to form hydrophilic carbonyls. Less than half of these intramembrane products continue on into the organism for further oxidation. Most escape to the environment. Because active transport is now required for reprocessing these products have very long half-lives, sometimes of the order of centuries. Metabolic product stability exceeds that of hydrocarbons in seawater so that a mechanism exists for long-term accumulation of these carbonyl products in the environment.

Like the oxidation products of DDT, it is mostly the products of oxidation that are responsible for hydrocarbon toxicity. The toxicity of crude oil increases following partial processing by microorganisms, and Alyeska consultants found that ballast water treatment pond effluent remained inhibitory after the volatile hydrocarbons had been removed. In higher unlike the dioxygenase systems of hydrocarbon degrading bacteria. Suspected compounds are somewhat uncommon moderate chain-length organic acids with additional functional groups. Important members still lack published mass spectra.

Following the discovery that large amounts of oxidation products are released by the microbial metabolism of hydrocarbons by conventionally-isolated bacteria, new techniques were developed for the cultivation of what is believed to be the more typical marine bacteria present as discussed above. The first of these isolated, *Oligobacterium* RB 1, is of record small size, only 0.06 μm^3 in volume. This organism, randomly selected from Resurrection Bay seawater, will grow on a large number of substrates including toluene. Like conventional isolates, it produces large amounts of these oxidation products of metabolism. Moreover mixed cultures from the ballast water treatment pond in Port Valdez liberate these products as well. It is our goal to understand the behavior of typical marine bacteria in general with particular reference to general ecosystem function. In this project we propose to focus on metabolism of anthropogenic hydrocarbons by these organisms in an effort to predict how the system, including higher organisms might respond to chronic pollution. Related programs are funded at a modest level by the US Environmental Protection Agency Office of Exploratory Research and By Ocean Sciences at the National Science Foundation.

NEED FOR THE PROJECT

Dissolved hydrocarbons appear to remain in the marine environment for hundreds of years. Those that are microbially oxidized liberate products of metabolism that are toxic. Similar toxic products of metabolism probably enter the marine system by incomplete treatment of ballast water. However precise chemical characterization of these compounds has not yet been performed and specific toxicological studies are therefore absent. While Prince William Sound is subject to hydrocarbon input from various sources, detailed studies of hydrocarbon bioconversion, and particularly the potential effects of those bioconversion products on other organisms, are absent. Most studies are restricted to observation of short-term death rates following exposure to weathered crude oil. However these LD 50's overlook the effect of irritants on indigenous species. Studies here represent a more general approach with attention to the molecular mechanisms involved. While some studies of the populations involved in hydrocarbon degradation and toxic product production exist, the vast majority of the responsible organisms are eliminated from consideration by the methods used. The proposed program will provide a modern account of Prince William Sound Microbiology with particular emphasis on hydrocarbon degrading ultramicrobacteria, and evaluate the roles of these organisms in i) recycling organic carbon to higher organisms, and ii) converting influent hydrocarbons to toxic compounds.

PROJECT DESIGN

A. Objectives

1. Provide contemporary measurements of hydrocarbon concentrations in Prince William Sound.
2. Determine the fraction of total PWS bacteria that are capable of oxidizing hydrocarbons.
3. Test random extinction-culture isolates of indigenous bacteria for inducibility toward hydrocarbons.
4. Identify the products of metabolism of aromatic hydrocarbons on representative cultures.
5. Identify the toxicological mechanisms of specific ring-cleavage products produced.

B. Methods

1. Hydrocarbon concentrations are obtained by purge and strip techniques.
2. The fraction of bacteria with constitutive ability to oxidize hydrocarbons is observed by autoradiography with total populations characterized by high resolution flow cytometry.

- 3. Random marine bacteria are selected by extinction culture. Their ability to metabolize hydrocarbons is evaluated, following exposure to ug/liter inducing concentrations of hydrocarbons, by collection of the products of metabolism from radiolabeled hydrocarbons.
- 4. Products of metabolism of aromatic hydrocarbons by these cultures are initially located by the affinity of those products for acidic aqueous media. Detailed characterization is by derivatization within the aqueous phase, solvent-extraction, fractionation on silica gel columns, and analysis of the resulting fractions by gas chromatography for evaluation of the total compounds present, and by mass spectrometry for chemical identification (methods now under development).
- 5. The offending compounds will be examined by published methods for cytotoxicity, and teratogenicity, for their influence on sensitive enzymatic processes by newly developed enzymatic procedures, for their influence on species interactions by success in interspecies competition in nutrient-limited experiments and chemotactic avoidance behaviors.

C. Schedule

	Year 1	Year 2	Year 3	Year 4	Year 5
Hydrocarbon measurements	----	----	----	-----	
Total and hydrocarbon oxidizer populations	----	----	----		
Obtain extinction culture isolates	----	----			
Develop extinction culture isolates	-----	-----	-----		
Examine for hydrocarbon oxidizing capacity	-----	-----	-----		
Identify ring cleavage products of metabolism	-----	-----			
Evaluate toxicity of biooxidation products			-----	-----	
Data synthesis					----

D. Technical Support

Project investigators are competent in all proposed aspects except toxicity which will be done in collaboration with colleagues.

E. Location

Cruise locations will include Prince William Sound near currently-contaminated beaches and in Port Valdez where discharge of the offending compounds is suspected.

PROJECT IMPLEMENTATION

The project should be implemented at the Institute of Marine Science, through the School of Fisheries and Ocean Sciences because it is uniquely capable of doing so. Unique capabilities include:

1. Capabilities for cultivating ultramicrobacteria.
2. Availability of flow cytometry with sufficient sensitivity for enumerating, sizing, biochemically analyzing, and physically sorting marine bacteria.
3. Capabilities of characterizing hydrocarbon oxidizing ultramicrobacteria, previously unknown and unrecognized in oil-contaminated sediments, as a major player in beach restoration.

Other relevant areas of special expertise include:

1. An understanding of hydrocarbon bioconversion kinetics, i.e. how bioconversion rates respond to hydrocarbon concentrations from both theoretical and experimental aspects.
2. An understanding of flow cytometry from both theoretical and experimental aspects. This allows, for example, use of light scatter theory to size marine bacteria including those so small that they have previously been ignored, and to account for differences in shape and refractive index, as well as size on the signal produced from seawater samples.
3. Familiarity with the concentrations and disposition of dissolved hydrocarbons produced from the *Exxon Valdez* oil spill, and expected decomposition rates through direct measurements. This was first reported in our discovery of monoterpenes as a normal hydrocarbon constituent of Prince William Sound.
4. Familiarity with the types of compounds expected to be produced by the metabolism of anthropogenic hydrocarbons through laboratory experiments and an ongoing program for their identification and quantification.
5. An understanding of how oil-phase hydrocarbons coat gravel, and how this coating extracts dissolved hydrocarbons passing through them (Alaska Science and Technology final report and in preparation).
6. Equipment purchased and a developing program for the characterization of newly isolated hydrocarbon-oxidizing ultramicrobacteria from patterns generated on state-of-the-art two-dimensional electrophoresis.

7. Some understanding of thermodynamics of whole biological systems which allows consideration of ecosystem interactions, now sometimes called "global physiology".
8. Familiarity with the mechanisms of active transport, and have proposed a new one (vectorial partitioning) for the sequestering of hydrocarbons to accompany the three known forms.
9. Ability to evaluate *in situ* hydrocarbon oxidation rates following the development of sensitive new methods.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The project will stand alone. Experts in this laboratory include B. R. Robertson, a microbiologist with exceptional skills in flow cytometry, and Dr. Luis Pinto, a geochemist with skills in the quantitative analysis of the organic compounds in seawater. We will work closely with colleagues in a number of areas.

FY 95 BUDGET (\$K)

Personnel	74.0
Travel	4.0
Contractual	7.1
Commodities	2.0
Equipment	0.0
Indirect Costs	36.4
Subtotal	123.5
Indirect Costs	11.6
Total	135.1

Historical Analysis of Sockeye Salmon Growth Among Populations Affected by Overescapement

Project Number:	95048
Restoration Category:	Monitoring (new)
Proposed By:	Natural Resource Consultants, Inc.
Lead Trustee Agency:	ADFG
Cost FY 95:	\$99,200
Cost FY 96:	\$16,600
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Kenai River, Akalura Lake, Red Lake, Coghill Lake, Chignik Lake, Kasilof River, Crescent River, Wood River Lakes
Injured Resource/Service:	Sockeye salmon

INTRODUCTION

The *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) has identified several sockeye salmon stocks that are not recovering from the overescapement caused by the *Exxon Valdez* oil spill. Injured sockeye salmon stocks include sockeye from the Kenai River in Upper Cook Inlet, and Akalura Lake and Red Lake on Kodiak Island. Additionally, the EVOSTC is funding a restoration project on Coghill Lake near Prince William Sound (lake fertilization to enhance growth), although the declining sockeye runs have not been linked to the oil spill. Although the EVOSTC did not list Chignik Lake as a potentially injured lake, Chignik Lake received more than twice its escapement goal as a result of the oil spill in 1989. Monitoring of Chignik Lake in relation to the overescapement has not been conducted.

Overescapement of sockeye salmon to these lake systems is believed to have led to exceptionally high densities of salmon in the lakes, which in turn has caused reduced growth. Schmidt et al. suggested that small sockeye fry in the fall cause exceptionally high mortality during winter, a period when sockeye salmon may lose 10% body weight because few or no prey are available.

Presently, the EVOSTC and the Alaska Department of Fish and Game (ADFG) are monitoring fry abundance and size in the Kenai River system and smolt abundance and size in Akalura Lake and Red Lake. However, monitoring of sockeye smolt lengths in these systems began only recently. Few years of data are available for comparison before and after the overescapement. Thus, the effect of overescapement on salmon growth is difficult to evaluate. Furthermore, growth of sockeye smolts migrating through oiled waters, especially in Prince William Sound, may have been reduced. This effect has been documented for pink salmon. To our knowledge, the early marine growth of sockeye salmon from the areas affected by the *Exxon Valdez* oil spill has not been examined.

Scale measurements offer a relatively inexpensive means to evaluate the effect of overescapement in freshwater and oil in the marine environment on sockeye salmon growth. Scale measurements can also be used to inexpensively evaluate the recovery of the sockeye populations. Sockeye salmon scales are correlated with fish length and have been used to describe sockeye salmon growth in lakes and the ocean.

The objectives of the proposed project are to:

1. Measure annual growth zones of sockeye salmon before, during, and after the oil spill from systems affected by the oil spill (Kenai River system, Akalura Lake, Red Lake, Coghill Lake, Chignik Lake) with sockeye growth from systems less affected by the oil spill (Kasilof River, Crescent Lake, Black Lake, and the Wood River Lake system),
2. Compare trends in annual growth zone measurements of sockeye from systems affected by overescapement or oil in the marine environment with that of systems not affected,
3. Determine the relative magnitude of reduced sockeye growth in freshwater or first year at sea as a result of overescapement or the presence of oil in the marine environment and evaluate the recovery of sockeye growth in years subsequent to the spill.

NEED FOR THE PROJECT

The declining sockeye runs to the Kenai River, Red Lake, and Akalura Lake are believed to be related to reduced growth caused by overescapement. The effect of large escapement in Chignik Lake has not been evaluated. Additionally, the effect on growth of Coghill Lake sockeye migrating through oil-contaminated waters in Prince William Sound has not been evaluated, although Willette demonstrated that growth of pink salmon in Prince William Sound was reduced.

Efforts to monitor the size of sockeye salmon smolts emigrating from these lakes began only recently and few data are available for comparison prior to the oil spill. In order to document the magnitude of the effects and the recovery of salmon in these areas, measurements prior to the spill, during the spill, and subsequent to the spill are needed. Scale measurements, which are an index of salmon growth, offer an inexpensive means to monitor the recovery of sockeye salmon in these affected areas. Furthermore, detailed analyses of freshwater and marine growth of sockeye from oil-affected and unaffected stocks over the past 20 years could help identify non-spill factors influencing growth and production. Thus, the use of scale measurements of a variety of sockeye stocks will enable us to distinguish effects of the oil spill from other environmental factors.

PROJECT DESIGN

Adult sockeye salmon scales would be obtained from ADFG for each of the populations described above. ADFG collects these scales as part of their normal management activities. Scales are available back to at least 1970 for sockeye stocks in the Kenai River, Kasilof River, Red Lake, and Coghill Lake stocks. Akalura scales are available back to at least 1985. Scales for Chignik Lake, Black Lake, and Wood River Lakes sockeye stocks are available back to 1920; these scales have already been measured through 1990. Thus, scales measurements need be updated for these only stocks.

At least 100 scales from the dominant age group of each stock will be measured for each year. This sample size was determined to be adequate by Zimmermann. The scales will be measured by the Optical Pattern Recognition System (OPRS) at Dr. Donald E. Rogers' laboratory at the University of Washington. The scale measurement methodology will follow that described by Zimmermann, who was a graduate student supervised by Dr. Rogers and Dr. Ruggerone.

Annual frequency distributions of scale measurements will be plotted and analyzed for normality. Skewness of the frequency distributions may indicate size-biased mortality, which may indicate the effect of predation on smaller individuals. Trends in scale growth measurements will be analyzed within and among sockeye stocks in relation to the overescapement and oil spill events.

Scales available through 1995 will be measured, analyzed, and reported during FY95. Scales collected during 1995 represent the last progeny of the 1989 brood year. Scale collected during 1996 and 1997 represent progeny of sockeye spawning after the spill. Thus, we recommend two additional years of investigation (FY96, FY97) to examine the recovery of the sockeye stocks. These two years of investigation would be conducted at a much lower cost.

PROJECT IMPLEMENTATION

The project will be conducted by Dr. Gregory T. Ruggerone, Natural Resources Consultants, and Dr. Donald E. Rogers, Fisheries Research Institute, University of Washington. Both Ruggerone and Rogers have extensive first-hand experience with interpretations of scale measurements and have published numerous papers involving sockeye salmon scales. This team offers excellent qualifications and has available the needed equipment to conduct the investigation.

COORDINATION OF INTEGRATED RESEARCH EFFORT

ADFG will provide sockeye scales for each of the stocks described above. These scales were collected as part of the ADFG's routine management activities. Sockeye scales from Chignik Lake and the Wood River system have already been measured and transferred to a computer database for return years 1950 to 1990. Thus, scale measurements for these stocks need only to be updated.

FY 95 BUDGET (\$K)

Personnel	7.2
Travel	0.0
Contractual	85.0
Commodities	0.0
Equipment	0.0
Subtotal	92.2
Gen. Admin.	7.0
Total	99.2

Large-Scale Coded Wire Tagging of Prince William Sound Herring

Project Number:	95051
Restoration Category:	General Restoration (new)
Proposed By:	Natural Resources Consultants, Inc.
Lead Trustee Agency:	ADFG
Cost FY 95:	\$231,900
Cost FY 96:	\$514,800
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring, commercial fishing

INTRODUCTION

The *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) has identified several fish stocks that are not recovering from the effects caused by the *Exxon Valdez* oil spill. Prince William Sound herring is one of these stocks. Population biomass has unexpectedly declined from over 130,000 tons in 1992 to about 7,000 tons in 1994 due mainly to the demise of a particularly strong 1988 year class of herring that was anticipated to support large harvests and future year classes through spawning escapement.

The 1993 herring run to Prince William Sound was approximately 100,000 tons below expected abundance resulting in severe commercial fishing restrictions. Returning fish were observed to have VHS disease and were in a weakened state with unusual behavior. In 1994, the herring run further declined to less than 7,000 tons below the 8,400 ton minimum required to allow any commercial fishing and fish were again found with evidence of VHS disease.

The current level of biomass and age composition of the population indicates the 1996 commercial fishery may have to be curtailed and future commercial fisheries harvests will likely be reduced compared harvests of the past five to eight years. Herring stocks and fisheries in other areas of Alaska appear to remain healthy and some are continuing to expand.

Numerous theories have been proposed to explain the decline in Prince William Sound herring stocks including long-term effects of the *Exxon Valdez* oil spill, limitations on food supply, competition with pink salmon hatchery releases, and effects of the VHS disease. Oil spill

effects studies have shown the possibility that egg, larvae, and juvenile herring were, and may continue to be, affected by the presence of oil. Genetic damage, reduced immune response, and possible lowered reproductive capacity are but a few of the potential oil spill related effects that are likely to have been felt by the 1988, 1989 and possibly later year classes of herring in Prince William Sound. Chronic low-level oil contamination may be further affecting recent year classes.

Critical to the study of Prince William Sound herring stock recovery is accurate determination of population size, differential growth, disease occurrence and mortality between oiled and un-oiled areas, and migration of potentially genetically damaged fish from affected areas to unaffected areas. ADFG currently relies mainly on inseason aerial surveys and test fisheries and post-season on spawner deposition and age-structured modeling to determine the size of the returning herring population in Prince William Sound. These same techniques combined with samples of fish from the commercial fishery provide information on the age composition, size and weight at age, fecundity, and location of spawning deposition. ADFG is aware these stock assessment tools are subject to error which may vary from year to year depending on stock size, level of commercial fishery, and environmental conditions. Not enough is known about the physical and biological factors that determine early life survival or those that control adult maturation and spawning. For example, the 1988 year class appeared particularly strong in 1992 as four year-old fish and then unexpectedly declined drastically at age five and further at age six in stark contrast to the population dynamics of similar strong year classes in the recent past which persisted in the population through age seven.

Currently ADFG places its greatest reliance on spawner deposition surveys to provide a means of back-calculating the spawning biomass of herring each year. When combined with the commercial harvest, this estimate provides the overall annual run size and allows calculation of exploitation rates, and inputs into the age-structured stock assessment model to predict next year's run size and possible commercial harvest. The accuracy of these population estimates drives the predictive process. Skip-spawners (herring that return but may not spawn), the spread of the geographical location of spawning, and the distribution of the commercial fleet all may affect the accuracy of these estimates.

Large-scale coded wire tagging would provide an additional useful tool to estimate population size while providing important additional information on growth, health, fecundity, and migration patterns of herring.

The objectives of the proposed project are to:

1. develop a large-scale coded wire tag release and recapture program for herring in PWS,
2. create a coded wire tag return database that would be available to researchers working in Prince William Sound and other areas,
3. assist researchers in analyzing coded wire tag returns to answer specific questions for research and management.

NEED FOR THE PROJECT

The declining herring stock in Prince William Sound is creating an economic hardship for commercial fishers and the communities that depend on the harvest of this resource. Herring is an important food source throughout all stages of its life history for many other important species in Prince William Sound. Reduction in the stock size of herring may inhibit the recovery of other fish, birds, and marine mammals.

ADFG budget constraints do not allow the initial capital outlay for development of such a project. However, once in place with equipment purchased, technicians trained, and databases developed, ADFG may be able to continue a large scale herring tagging program beyond the end of the proposed project period.

PROJECT DESIGN

Experts from Natural Resources Consultants and Northwest Marine Technology along with support from ADFG will develop a coded-wire tagging program for Prince William Sound. Historical harvest and spawning patterns will be reviewed, fishers and processors will be contacted, researchers and fishery managers will be interviewed, and a detailed tag release and recovery plan developed.

Recently developed statistical procedures using marked-tag recovery techniques on large-sized fish populations require far fewer tag releases and recoveries than the traditional Petersen estimates (see attached description). We anticipate that four Mark-4 tagging units would be purchased (or borrowed from ADFG salmon tagging programs). Northwest Marine Technology has achieved tagging rates from 800 to 1,000 herring per hour with the Mark-4 units in the North Atlantic. The units would be completely self-contained and portable. They could be used together on a tagging vessel or spread separately throughout the Prince William Sound area.

Live herring for tagging will be obtained from test fishery purse seiners, chartered commercial seiners prior to and after fishery openings (or during the entire 1995 season when no commercial fishery is expected), and from pound herring prior to release. The latter source would provide evidence of the relative survival rate of herring used in the pound fishery which could result in management allowing an expansion of this fishery. Assuming that each Mark-4 tagging unit was kept busy for a conservative ten hours per day over a ten day period each season, it is not unreasonable to estimate that up to 300,000 herring could be tagged and released each season. Using recently developed large population mark and recapture population estimate techniques, as few as 60,000 tagged fish may need to be released to get a reasonably accurate estimate of the population size.

Herring are processed at approximately four locations in Prince William Sound each year. Processing lines would have NMT large volume detection units installed. These units have been proven in other large-scale fisheries such as North Atlantic herring. They detect coded

wire tags under a continuous flow of fish and divert a "batch" of fish that are then further scanned for tags with a smaller volume automatic detector or by use of a hand-held detector. The four detection units proposed for the study should be able to scan a majority of the herring processed in Prince William Sound each year for coded wire tags. In 1995, the project will focus on maximizing tag releases. In 1996 and 1997, the project will focus on both tag releases and recoveries.

A computer tag release and recovery database will be developed by the team using input from ADFG, NMFS, and researchers active in Prince William Sound and other areas where the data may have application. Additionally, tag data use support services will be offered to all interested researchers and managers. These support services will include specific sample design, access and instruction in the use of the database, and a dial-in computer bulletin board format for information on tagging data availability and downloading protocols. At the termination of the three year project all tagging equipment and the coded wire tag database will be supplied to ADFG for continued operation.

PROJECT IMPLEMENTATION

The project will be conducted by Natural Resources Consultants and Northwest Marine Technology. Mr. Jeffrey A. June and Mr. Guy Thornburgh will develop the tag release, recovery, and tag reading program in conjunction with the representatives from the ADFG.

Dr. Greg Ruggerone, Dr. Gary Morishima, and ADFG to develop the coded wire tag database structure and outside research and management information support.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The project team will integrate the project design, tag release, tag recovery, and database utilization with any other relevant ongoing or planned projects in the area. The team will assist other researchers and fishery managers in integrating the information collect in the herring coded wire tagging project into their studies and make available the herring coded wire database to all interested users. In addition to studies directed at herring, the coded wire tag program could be useful in a variety of other studies ongoing in Prince William Sound. For example, coded wire tags from herring could even be hand-scanned for in fish, mammal, and bird stomach or scat studies to provide additional information on feeding habits.

FY 95 BUDGET (\$K)

Personnel	20.4
Travel	0.0
Contractual	194.8
Commodities	0.0
Equipment	0.0
Subtotal	215.2
Gen. Admin.	16.7
Total	231.9

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Community Involvement and Use of Traditional Knowledge

Project Number:	95052
Restoration Category:	General Restoration (new)
Proposed By:	ADNR
Cooperating Agencies:	ADFG, USFS, DOI
Cost FY 95:	\$230,500
Cost FY 96:	\$248,400
Total Cost:	Unknown
Duration:	5 years (project could be 1-year only, or multi-year as expand to other communities in the spill area)
Geographic Area:	Oil spill area
Injured Resource/Service:	Subsistence

INTRODUCTION

The *Exxon Valdez* oil spill in 1989 caused severe disruption of the lives and perceptions of many spill area inhabitants and communities about their surrounding environment. Scientific studies have occurred throughout the spill area with researchers mostly based in agencies or institutions in Anchorage, Fairbanks, or outside Alaska. Data is collected under research strategies dictated by generalized knowledge of local environments but with little detailed historical knowledge. That lack of knowledge frequently diminishes application of results to specific local needs. It intensifies the frustration of local subsistence users and sense of loss of their historic lifestyle.

Traditional knowledge is used for this project to describe personal observations by people living in the spill area and knowledge which has passed from generation to generation by members of communities who share a common cultural heritage. This project intends to develop a multicultural partnership between the people of the oil spill region and scientific investigators carrying out detailed studies of the ecosystem of the region.

One Elder of the village of Tatitlek was noted as saying that, while flying to Tatitlek from Chenega Bay, he could see the bottom in places where it had not been evident before and he wondered what effect this obvious lack of plankton would have on the salmon runs. He made this observation in 1992 and again in 1994. Another example of local knowledge based on observations of past local conditions was recognition of the lack of herring spawn on seaweed in Tatitlek Narrows which is gathered each year by the local people. Herring spawn is an important part of the spring diet and valued delicacy of Tatitlek people. This is the type of traditional knowledge that would be valuable in understanding the long term effects of the *Exxon Valdez* Oil Spill.

NEED FOR THE PROJECT

Researchers have recognized that local residents have traditional knowledge that could help them answer questions they have not been able to answer through conventional scientific means. For example, people living in the spill area have detailed knowledge about condition of resources, including seals, eel grass beds, archaeological sites, etc., which can significantly add to data of scientific studies and enhance application of results. Local people have stated their desire to add local knowledge for the benefit of researchers and be involved in all stages of projects. Presently there is no mechanism to bring the two groups together to share their knowledge. The project will initiate a mechanism and protocol for accomplishing those goals. Much of the documented damage and related research has been in the Prince William Sound and Outer Kenai Peninsula areas and the initial phase of this project will focus there. Successful implementation of the FY95 program will be followed by expansion to other communities, especially the Kodiak area, where scientific research and traditional knowledge can complement each other.

PROJECT DESIGN

A. Objectives

The objective of the project will be to aid science project researchers to involve the local people into their studies either by making use of unique local knowledge, incorporating research aims which are locally important, and facilitating feed back of study results to the appropriate study area residents.

B. Methods

In each of three pilot communities a local person will coordinate efforts of knowledgeable local people, arrange local support and equipment for scientific investigators and communicate back to the local community the information and findings generated by scientific investigations in the local area. The local coordinators will be selected based on their knowledge of local natural and cultural resources. They will receive a part-time salary and will be selected and paid by the

contracted area wide coordinator. The area wide coordinator will be selected by evaluation of proposals solicited by RFP and appraised by a panel of agency resource specialists.

This project will be structured on the stewardship concept with a contracted spill-area-wide coordinator who works with local community coordinators to assure comparability of aims, policy and procedures between the local programs. The first year of the project will involve three communities, to refine the process and provide a pilot program to be expanded to other communities in subsequent years. A listing of all scientific studies funded by the Trustee Council during FY95 in the area of each village will be compiled. Also a list of local knowledgeable people and people able to provide support on contract will be assembled by the local coordinator. That list will be provided to the overall coordinator who will provide it to researchers. The local coordinators will also be responsible for compiling information and sources of additional local information about spill affected resources other than just the resources subject to current scientific research. That will allow local residents to help identify important research questions related to the spill.

Reimbursement of local participants will be arranged, if applicable, between the local participants and scientists conducting studies in the area. The local coordinator will act only as a facilitator to help investigators find locally knowledgeable informants and operators equipped for support services if required.

A contracting officer representative will assist the contractor to comply with agency contracting requirements and act as liaison between the agency and the contractor.

Local coordinators will be selected and brought into Anchorage to attend a meeting tentatively scheduled for January 1995 to share findings of various scientific projects. Immediately prior to or after the general meeting, local coordinators will meet to plan implementation of the Community Knowledge Transfer project in the selected communities.

Proposals submitted in response to the Request for Proposals will detail how the local coordinators will function, which communities will support the program and a sample of how lists of client scientists and similar lists of local resource people will be maintained. The proposals will be reviewed by a committee of agency specialists including scientists familiar with investigations in the spill area of the different resources and an individual representing local interests. The kinds of data the project should cover are, for example, fish, sea mammals, birds, intertidal habitat, and archaeological sites which are among the many studies being proposed for FY95. Proposals will be submitted in the format of detailed work plans including a narrative describing the program proposed and details of the proposed budget.

C. Schedule

November 15, 1994	RFP Published; 30 day response to RFP
December 15, 1994	Proposals evaluated and contractor selected
January 15, 1994	Oil spill science meeting/training for local coordinators
February 15, 1995	Study lists to communities
March 15, 1995	Local lists to researchers
July 1, 1995	Project status report to Trustees
September 30, 1995	Final project report

D. Technical Support

No technical support will be necessary for the project as it is a coordination project between local people and projects each with its own technical support requirements.

E. Location

This project is located in the Prince William Sound and Lower Cook Inlet areas. The communities proposed are Tatitlek, Chenega Bay, and Port Graham.

PROJECT IMPLEMENTATION

This project should be implemented under contract with a group or individual experienced in coordinating studies in the rural communities of the oil spill area. The contractor should have training in social sciences and experience in cultural anthropology or sociology. The contractor should also be familiar with traditional environmental knowledge.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This is a coordination project rather than a research project and as such is directly aimed at integrating research studies with local informants and resource users.

FY 95 BUDGET (\$K)

Personnel	55.0
Travel	18.0
Contractual	139.5
Commodities	0.0
Equipment	0.0
Subtotal	212.5
Gen. Admin.	18.0
Total	230.5

Movement of Larval and Juvenile Fishes within Prince William Sound

Project Number:	95057
Restoration Category:	Research (new)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	NOAA
Cooperating Agency:	ADFG
Cost FY 95:	\$328,100
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

Prior to the *Exxon Valdez* oil spill, there had been no baseline studies conducted to document presence, absence, distribution or abundance of larval or juvenile fishes in Prince William Sound (PWS). As a result of research conducted following the oil spill in 1989 several important issues regarding the fate of larvae and juveniles have arisen. McGurk et al. note that future research on early life history should be designed and conducted in order to answer questions related to fisheries ecology and management. An ecosystem approach addresses questions about fishes such as predator/prey relationships, physical processes affecting natal habitat, environmental factors controlling recruitment, the relationship between transport of larvae and surface and subsurface currents in the sound, and location and condition of juveniles in the winter. This study proposes to fill the gap between SEA and the Forage Fish and Seabird and Mammal studies by following patches of herring and other larval fishes on transit through PWS to identify areas of aggregation used as juvenile nurseries.

Forage fishes (herring, pollock, sandlance, capelin, northern smoothtongue) are the target species of this study. These species are important food for marine birds and mammals which are listed as not recovering. Additionally, Pacific herring is one of the species listed by the EVOS Trustee Council as damaged and not recovering. This species experienced poor recruitment in 1993, when the 1989 year class would have been expected to enter into the fishery. In addition to low returns, herring have been plagued with VHS, a viral disease which contributed to sound-wide failure of the herring fishery in both 1993 and 1994.

NEED FOR THE PROJECT

Knowledge of dispersal of the larval stages of fishes is a significant gap in understanding the life history of forage fishes. Dispersal of herring and pollock larvae in 1989 indicated that larvae move from northeast to southwest through the sound with the current, analogous to the path followed by the oil following the *Exxon Valdez* oil spill. This suggests that larvae may exit PWS and recruit as juveniles to areas downstream, i.e., Kenai Peninsula and Kodiak Island. One year of well-designed fisheries and physical oceanographic studies are needed to confirm this. Knowledge of the movement of larvae through the sound can be used to identify areas where juveniles aggregate, both within and outside the sound. After year one, these results will be used to efficiently design sampling in key areas important for rearing juvenile fishes.

An ecosystem approach is needed now because lack of such an approach immediately following the oil spill is causing interpretation of some of the previous data to be questioned. A conclusion of the 1989 larval fish study was that movement of larvae is related to current patterns in PWS, but flow patterns are more intricate than indicated by the pathway taken by the *Exxon Valdez* oil. Peer reviewers of papers submitted based on those results questioned the interpretation of winds and currents acting in the same way on oil slicks and larvae in the water column because comprehensive associated oceanographic data were lacking. Additionally, larval herring collected in oiled areas of PWS following the *Exxon Valdez* oil spill which experienced morphological and cytogenetic damage are being questioned. Unfortunately, the relationship between damaged herring and spilled oil cannot be directly made because, without the supporting oceanographic data, we can only infer but not prove the larvae moved through oiled areas. Peer reviewers have cited these as "interesting observations...tempting to make the association ...cannot be justified because we do not know which larvae may or may not have been exposed to oil...situation is compounded by the lack of baseline data."

Currents in PWS may create differential effects on larvae depending upon their spawning location. If larvae from the southern spawning grounds disperse at a faster rate than larvae from northern spawning grounds, that may indicate habitat for juveniles is concentrated in the northern half of the sound. Using a coordinated oceanographic-based ecosystem approach we intend to determine what percentage of larvae may be transported out of the sound. The amount and timing of wind and buoyancy-driven flushing of the upper layers of PWS during April and May will have a significant effect on larvae. When the sound is acting like a "river" larvae may quickly be passed through the sound resulting in nursery areas downstream in locations as far as the Kenai Peninsula. When the sound is acting like a "lake" larvae may be

retained in the sound and thus be dependent upon food available within the sound. By learning where the larvae are transported, we can determine the location of nursery grounds and use that information to efficiently design future studies.

PROJECT DESCRIPTION

A. Objectives

The overall objective of this project is to understand the distribution and abundance and the resulting interannual variability in successful year classes of fishes in PWS. This can be accomplished by examining the fish in the context of their total environment including the meteorology and oceanography driving the system and the biology of the lower trophic levels which act as food for fish larvae. The larval fish aspect of the ecosystem study will achieve the following objectives:

1. To identify and count all larval fishes collected.
2. To determine the relationship between observed distribution of fish larvae and broad scale oceanographic patterns.
3. To use patches of herring larvae as markers and follow them from beach deposition throughout their passage within PWS.
4. To determine if local oceanography differentially affects herring larvae spawned at separate locations.
5. To project the locations of nearshore nursery areas for age-O fishes from the movement of the larvae coupled with the oceanographic conditions.

B. Methods

The logistics of this project will be in cooperation with the other components of the proposed ecosystem study, therefore specific needs for vessels are not included here. The assumption is that there will be a vessel available with capabilities for towing a Tucker trawl (1 m² plankton net) and that the vessel will concurrently be used by this fisheries oceanography project and the physical oceanography project.

Herring was the third most abundant larval fish collected in PWS in 1989, but it is the only one for which we can identify spawning areas. Therefore, herring larvae will be used as markers and their movement will be followed throughout the sound. Immediately following deposition of herring eggs in April 1995 two patches of larvae will be tracked. These two patches of herring which originate in different areas of the sound will be followed to determine the effect of local oceanography on recruitment success. Comparisons of herring from two different areas will reveal if local oceanography affects survival of larvae from separate locations disparately. A

major spawning site in the northeast portion of the sound and one near Hinchinbrook Entrance or Montague Strait will be identified and herring larvae from those key sites will be followed as they move through the sound. Sample locations will initially be based on ADFG overflights to identify spawn deposition.

Patches of larvae will be identified and sampled on a scale of daily to weekly or longer, dependent upon weather conditions and speed of patch movement. Sampling of two separate patches of larvae will be coordinated so that they are not sampled simultaneously and the same boat is used for all sampling. One or more drogues (in component of Physical Oceanography - 94320M) will be released into each patch as transport away from the beach begins. Current speed and direction will be measured using an Acoustic Doppler Current Profiler (Physical Oceanography - 94320M). Sampling for larvae will continue through July, thus encompassing the season of larval herring, pollock and capelin growth and movement through the sound.

To relate the observed distribution of larvae to broad scale oceanographic patterns of flow, sampling transects will be in line with the water flow. Each sampling day a transect will be run from outside the trailing edge of the patch, through the patch, to outside the leading edge. The trailing edge of transects on successive days will overlap the leading edge of the transect the day before. Net sampling in conjunction with drogues will be used to define the 2-dimensional size (long axis) of the patch. A minimum of five stations will be sampled per day, two outside and three inside the patch. As patches of larvae disperse with time and become larger, more stations will be sampled per day. Estimating the latitudinal extent of the patch will be dependent upon sophisticated hydroacoustic methods (Nearshore Fish - 94320N). Net tows will be used in conjunction with hydroacoustic methods to determine the vertical distribution of the target species. Net tows will also be used to groundtruth the hydroacoustic data by providing species composition, relative abundance and size data as all larvae will be identified and counted.

Sampling for larval fishes will be done with a Tucker trawl with mesh nets. Except for those tows used to determine vertical distribution of larvae for use with the hydroacoustics, all samples will be oblique tows covering the upper 50 m of the water column because 95% of larvae captured in May and June 1989 were in that depth range. Sampling for older juvenile fishes will require a different net to be designed, tentatively it is planned to be a small mesh seine and will be coordinated with the Nearshore (94320N) component.

As larvae metamorphose into juveniles, they are expected to move into nearshore nursery areas. An advantage of following a patch of larvae is to use the patch to locate nursery areas. Juvenile fishes will be sampled with nets and hydroacoustics (Nearshore Fish 94320N) in nursery areas along with concurrent oceanographic measurements of temperature and salinity with a CTD and water movement with an ADCP (Physical Oceanography 94320M). These data, together with information on the structure of the area (e.g. depth, distance offshore) will be used to classify the nursery habitat utilized by juvenile fishes. Characterization of juvenile habitat coupled with transport results can be used to project locations of nursery areas for forage fishes around and outside of the sound. These areas can then be investigated later in the season by the Forage Fish project and by the Nearshore Fish (94320N) project to determine which locations produce the most successful recruitment.

Fish will be separated from zooplankton and rough sorted to family groups by undergraduate students at UAF. Fish will be identified to species in Fairbanks by Michele Frandsen who is skilled in the identification of PWS fish larvae having ID'd all the larval fish collected in PWS in 1989. The standard length of all fish will be measured using a Wild MZ3 dissecting microscope and image analysis system (Bioquant) interfaced to a computerized data base (RBase). This process simultaneously enumerates the larvae as the length data are stored. Length will be measured for a subsample of individuals of each fish species. The precise age of a larva, in days, combined with hydrographic data can provide estimates of advection rates. Age of herring larvae can be determined in days and growth can be estimated following the methods of McGurk. Growth rates between sites and among years will be compared using an ANOVA. Because aging of daily growth rings in larval herring is time consuming it will only be employed on a small subsample of herring collected. For a larger percentage of herring larvae, we will employ a method of morphological staging. There is an overlap of size between substages, giving information concerning development of larvae along with size frequency. These data can expand the information gained from the smaller subsample of larvae which were aged.

A subsample of herring larvae will be examined for morphological deformities and assigned a Graded Severity Index analogous to that performed on the 1989 samples. A subsample of that will be sent to JoEllen Hose (Occidental College, Los Angeles, CA) for cytogenetic analysis. We expect the data obtained in herring larvae in 1995 to be within the morphologic and cytogenetic baseline range for normal larvae as newly hatched larvae in 1990 and 1991 fell within this range. However, older larvae have not been examined subsequent to 1989. It is expected that these samples will provide a baseline with which to compare 1989 and will validate the results obtained from 1989 samples.

All larval and juvenile fishes will be counted and measured. Distribution and abundance of each species of forage fish will be analyzed in relation to the oceanographic parameters and transport of larvae will be determined. From that, an estimate of retention of larvae within the sound will be made.

C. Schedule

November 1994 - January 1995

Write detailed study plan, coordinate with all companion projects and investigators based on results of 1994 sampling.

January - March 1995

Stage for FY95 field season.

April - August 1995

Field work in Prince William Sound, begin sorting and identification of larvae.

August - September 1995

Continue sorting and identifying larvae. Preliminary analysis of data.

For FY 1996, a continuation of this project will be requested to complete the workup of larvae and analysis of data. Only minimal field sampling will be required in 1996 because results of 1995 will be used to predict where the patch should move where the juvenile nursery areas should be.

D. Technical Support

This project requires strong supporting projects from the Prince William Sound Science Center (Physical Oceanography - 94320M and Nearshore Fish 94320N), Alaska Department of Fish and Game Spawn Deposition Study and ADFG Juvenile Herring new proposal). A subcontract to JoEllen Hose, Occidental College, Los Angeles, CA for cytogenetic analysis of herring larvae. Dr. Hose developed the techniques and conducted the analyses on the 1989 herring larvae.

E. Location

Sampling will take place in Prince William Sound. If there is significant transport of herring larvae out of the sound, it will be necessary to follow them along the Kenai Peninsula.

PROJECT IMPLEMENTATION

The lead agency on this project is proposed to be the University of Alaska Fairbanks because Brenda L. Norcross at UAF has the expertise to sample, identify and analyze larval fishes from Prince William Sound. She was the PI on a related project in PWS in 1989 and is familiar with the sampling techniques and the sample area. Having analyzed the previous data, she will use that information to design the study plan for the proposed study.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The proposed study is coordinated with the integrated Prince William Sound Ecosystem Assessment (SEA) which was initiated in 1994. This project is designed as an interdisciplinary study which focuses on transport of herring larvae but is dependent upon results of the concurrent Physical Oceanography (94320M) and Nearshore Fish (94320N) projects through shared data and resources and integrated sampling plans. This study will use results generated by Zooplankton in the Ecosystem (94320H), Phytoplankton and Nutrients (94320G), Avian Predation on Herring Spawn (94320Q) projects and the VHS study which was initiated in April 1994 on an emergency basis. This proposed study will contribute nursery area information to the newly proposed Juvenile Herring study and. The information gained from this proposed study will contribute to the PWS Herring Recruitment Model (new proposal). It will also be coordinated with the ongoing herring spawn deposition studies funded by ADFG and will be integrated with the newly proposed Food Limitation of Seabirds (NBS), Forage Fish (NMFS) and Marine Mammals (ADFG) studies. As part of this proposed project, Dr. Norcross will work directly with the PI's from the other project to integrate her results into their research.

FY 95 BUDGET (\$K)

Personnel	173.0
Travel	21.4
Contractual	21.6
Commodities	18.8
Equipment	15.8
Indirect Costs	50.0
Subtotal	300.6
Gen. Admin.	27.5
Total	328.1

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Restoration Assistance to Private Landowners

Project Number:	95058
Restoration Category:	Habitat Protection (new)
Proposed By:	USFS and ADFG
Lead Trustee Agency:	ADFG
Cooperating Agencies:	USFS, ADNR
Cost FY 95:	\$423,700 (includes \$68,500 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$0
Total Cost:	\$423,700
Duration:	1 year
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

The project is proposed to take advantage of opportunities to enhance or restore injured habitats or service values on private lands throughout the oil spill area. This differs from the Comprehensive Habitat Protection Process by focusing on site-specific mitigation and enhancement opportunities that can be implemented in conjunction with on-going development activities.

Injured resources and services that will potentially benefit from this project include: harlequin duck, marbled murrelet, pink salmon, sockeye salmon, Dolly Varden, cutthroat trout, river otter, sea otter, harbor seal, bald eagle, recreation, wilderness, archeological resources, and subsistence.

NEED FOR THE PROJECT

The project will provide information and assistance to private landowners who wish to minimize the impacts of their on-going and proposed activities on injured resources and services. Too often, impacts occur because landowners and development contractors lack awareness of resource sensitivities during pre-project planning. This is especially true of many spill-injured resources and services that are not specifically protected by law but, nevertheless, are important elements of a healthy and diverse ecosystem. Moreover, these resources may need additional levels of protection during their recovery period. The project will attempt to make development and restoration objectives compatible so that land use activities do not impede natural recovery. Enhancement activities may even accelerate the rate and degree of recovery for some resources and services.

PROJECT DESIGN

A. Objectives

1. Conduct an initial survey of normal agency responsibilities as they relate to on-going development activities that affect injured resources/services.
2. Identify critical requirements of the key habitats of injured resources or services.
3. Survey appropriate mitigation measures and best management practices that could be applied to the types of development that are occurring on private lands.
4. Contact private landowners to review development plans, discuss restoration options, and develop specific project proposals or funding requests.
5. Develop an annual report of various enhancement/restoration options for the Trustee Council to implement.
6. Prepare short and long-term maintenance and management plans (or agreements) for all Trustee Council-sponsored projects.
7. Develop a bibliography of best management practices, mitigation, and enhancement techniques for restoring injured resources/services that can be integrated with the *Exxon Valdez* Information Management System.

B. Methods

In addition to educating landowners on ways to protect injured resources and services, four different approaches are planned: enhancement, mitigation, reclamation/revegetation, and

monitoring/research. Examples are provided below.

Enhancement projects:

- increasing fish production by constructing fish passes, spawning channels, rearing areas and overwintering sites;
- developing coastal wetlands with impoundments;
- increasing bird production by constructing nesting boxes or islands; and
- installing recreational use amenities including trails and other access-related improvements as a result of Trustee Council acquisitions.

Mitigation projects:

- increasing stream buffers;
- modifying timber slash removal techniques;
- providing wildlife corridors;
- maintaining adequate wildlife cover;
- removing debris dams; and
- modifying the design or areal scope of development, timing and siting of support facilities to minimize impacts to critical life stages and key habitats.

Reclamation/rehabilitation projects:

- modifying planting techniques or plant species to accelerate revegetation;
- tree planting to accelerate forest maturity;
- removing or repairing perched culverts; and
- removing, stabilizing or revegetating discontinued logging roads.

Monitoring/research projects:

- evaluating the effectiveness of various mitigation techniques;
- inventorying injured species habitats; and
- assessing habitat quality as a function of on-going development activities.

As a practical matter, emphasis will be placed on projects that are cost-effective and immediately beneficial for restoring or enhancing injured resources and services. For example, timber operators could construct fish passes for injured pink salmon or expand the size of stream buffers to protect harlequin duck nesting as harvest operations are occurring in the field. This would minimize the cost of transporting personnel and equipment to remote sites and provide additional and immediate restoration benefits for these species.

C. Schedule

October 1, 1994 - June 1, 1995

Project planning, includes a survey of agency responsibilities and development recommendations, best management practices and current mitigation techniques, key habitat and use requirements for injured resources and services. Meetings with private landowners to develop restoration options. Presentation of restoration options to the Trustee Council.

Preparation of NEPA documents for public review and Record of Decision, as appropriate.

June 1 - September 30, 1995

Field inspections of potential project sites. Monitoring of construction or development activities to achieve restoration objectives. Continued meetings with landowners to identify additional opportunities for restoration. Preparation of project summary report for Trustee Council.

D. Technical Support

Technical support will be needed in the fields of forest ecology and management, project permitting, fisheries biology, wildlife conservation, mapping, and GIS.

E. Location

The project will initially focus on locations where development activities are occurring, or are planned to occur, throughout the oil spill area.

PROJECT IMPLEMENTATION

The project will be conducted as a cooperative effort between USFS and ADFG. Each agency has extensive experience in permitting timber harvests, mining, and other development projects on state and federal lands. Both agencies have worked together to design and implement restoration and enhancement projects for fish and wildlife.

COORDINATION OF INTEGRATED RESEARCH EFFORT

As noted, the project will be a coordinated effort between the USFS and ADFG. In addition, the project will utilize data and expertise from the Trustee Council's Habitat Work Group and produce a bibliography that can be integrated into the *Exxon Valdez* Information Management System.

FY 95 BUDGET (\$K)

Personnel	242.0
Travel	18.0
Contractual	90.1
Commodities	13.5
Equipment	13.0
Subtotal	376.6
Gen. Admin.	47.1
Total	423.7

River Otter Recovery Monitoring

Project Number:	95062
Restoration Category:	Monitoring (new)
Proposed By:	ADFG
Cost FY 95:	\$55,900
Cost FY 96:	\$0
Total Cost:	\$55,900
Duration:	1 year
Geographic Location:	Northern Knight Island and Esther Passage, PWS
Injured Resource/Service:	River otter

INTRODUCTION

River otters (*Lutra canadensis*) suffered direct mortality during the *Exxon Valdez* oil spill. A river otter damage assessment study in PWS conducted during 1989-92 documented subsequent long-term sublethal effects. No monitoring was done during 1993 or 1994, and therefore, recovery status is unknown. Monitoring of latrine sites that was begun during the damage assessment study will be continued for one additional year to establish an index of otter abundance that can be used to help assess recovery.

Signs of injury included changes in home range size, habitat use, and latrine abandonment. Home ranges of otters from oiled areas were twice as large as those from unoiled areas. Otters from oiled areas selected habitat differently. Latrine sites, which are an index to abundance, were abandoned more often in 1991 in oiled than in unoiled areas, suggesting there may have been a delayed response in river otter populations from exposure to crude oil. Differences in rates of fecal deposition between oiled and unoiled latrine sites in Herring Bay suggested otters used heavily-oiled areas less often.

Effects from exposure to crude oil were also indicated in blood and fecal samples. Increased levels of haptoglobins and interleukin were found in the blood of live-captured otters from oiled areas as compared to unoiled areas one and two years after the spill. Elevated levels of these blood values indicate trauma and a weakened immune system. Male river otters in 1990 had significantly lower body mass in oiled areas. By summer 1990, there were significant declines in the number of species in otter diets in oiled areas. Relative abundance of prey remains in otter feces showed strong differences between oiled and unoiled areas.

NEED FOR THE PROJECT

The restoration objective for river otter is a return to prespill habitat use, food habits, and physiological indices. The primary strategy for achieving this objective is to rely on natural recovery, to monitor that recovery, and to protect otters and their habitats. This project will provide the population monitoring information called for in the restoration strategy. It will also provide information essential for assessing the need for additional otter protection. Current trapping seasons in the oiled area may be curtailed or closed if the population is not recovering.

PROJECT DESIGN

River otter latrine sites are activity centers that provide the opportunity to monitor population trends and provide insights into the lower trophic levels that support otters. Once established by otters, sites are seldom abandoned unless significant changes occur in otter density or habitat. In 1991, latrine sites in areas within the path of the spill were abandoned at nearly four times the rate documented in unoiled areas. During the previous damage assessment study, intensive study areas were established in oiled and unoiled otter habitat. All latrine sites that were found in the two intensive study areas are available for continued examination in this study. Use of these sites by otters in 1990 and 1991 is documented and will provide the base for quantifying differences in otter use. Use will be compared in the oiled and unoiled study areas, and changes over time since the oil spill will be determined. Monitoring of latrine use will provide information on population trends within both study areas. The population trend within the oiled study area can be used as an indicator of the status of otter populations in other areas impacted by the spill. Trend data from the unoiled area will be necessary to separate the effects of weather from residual impacts of oil on population trends.

A. Objectives

1. Determine the annual level of latrine site use by river otters in the northern Knight Island study area and compare that use with data from the Esther Passage study area.
2. Monitor the annual harvest with emphasis on harvest size and the presence or absence of subadult animals from area impacted by the spill.

B. Methods

Methodology for cleaning otter scats and for determining latrine site abandonment will follow those used previously in the river otter damage assessment study. The same intensive study areas will be monitored. Field investigations of approximately two weeks each will occur in early June and September. During June, latrine site use or non-use will be determined and scats will be cleaned from the site. In early September, use or non-use will be determined.

Areas used as latrine sites are readily recognizable and have been identified in previous research. In addition to fecal droppings, otters keep the trails and a core area free of non-woody vegetation and light litter fall from the forest canopy. By summer, a lack of continued use will produce regrowth of vegetation and many small branches laying in formerly cleared areas. Also, lack of use will mean no scats will be deposited after the cleaning in early June. The trend in latrine site use will be determined and used as an indicator of the trend in otter population.

Trappers are required to bring river otter pelts to Alaska Department of Fish and Game for harvest sealing. Department fur sealing records for Game Management Unit 6 will be reviewed. Hide measurements may provide data on reproductive success. If sample size is adequate, it may be possible to identify subadults and evaluate recruitment into the population.

C. Schedule

Feb. 1 1995 Equipment and materials purchase. Initiate vessel charters and hiring of personnel.
June 1-14 First field trip; visit latrine sites to clear scats and determine use or non-use.
June 15-30 Field and harvest data analysis.
Sept.1-14 Second field trip; visit latrine sites to determine use or non-use.
Sept.15-30 Final report production.

D. Technical Support

No technical support required.

E. Location

Project study areas are northern Knight Island and Esther Passage.

PROJECT IMPLEMENTATION

Project should be done through competitive contract.

FY 95 BUDGET (\$K)

Personnel	17.3
Travel	1.0
Contractual	29.5
Commodities	2.5
Equipment	0.9
Subtotal	51.2
Gen. Admin.	4.7
Total	55.9

Monitoring, Habitat Use, and Trophic Interactions of Harbor Seals in Prince William Sound, Alaska

Project Number:	95064
Restoration Category:	Research (continuation of 94064)
Proposed By:	ADFG
Cost FY 95:	\$347,100 (includes \$114,700 for data analysis and report writing)
Cost FY 96:	\$338,400 (includes \$113,000 for data analysis and report writing)
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harbor seal

INTRODUCTION

This restoration monitoring and research proposal is written in collaboration with the interdisciplinary and integrative Marine Mammal Ecosystem program submission to the EVOS Trustee Council. Harbor seals are a non-recovering biological resource whose status affects subsistence uses and commercial fishing, both services which were negatively impacted by the EVOS. As outlined under the broad program direction, the goals of the combined collaborative Marine Mammal Ecosystem projects are to investigate, in an ecosystem context, the reasons for the long-term decline in harbor seals and their lack of recovery following the EVOS. In particular this project will focus on four questions which have been identified as the most likely explanation for the failure of harbor seals to recover following the EVOS: Is it food? Is it predation? Is it human impact? Is it disease?

Harbor seals (*Phoca vitulina*) occur year-round in Prince William Sound (PWS), where they pup, breed, molt, and feed. During extensive surveys of PWS in 1991-1993, 2,500-2,900 harbor seals were counted on haulouts. Another 1,700 were counted in the Copper River Delta and Orca Inlet. From 1984-1988, harbor seal numbers at trend count sites in PWS declined by over 40% due to unknown causes. In 1989, the decline was exacerbated in oiled areas by the *Exxon Valdez* oil spill (EVOS). More than 300 seals (36% of the seals in oiled areas) were estimated to have died in PWS because of the spill. Inhalation of light aromatic compounds, which caused brain damage that led to drowning, was the most likely cause of death. During molting-

period surveys in 1993, there were 51% fewer seals at oiled trend count sites than there were in 1988, compared to 11% fewer at unoiled sites. For all PWS trend sites combined, there were 27% fewer seals in 1993 than in 1988, and 57% fewer than in 1984. The reasons for the ongoing decline, and the lack of recovery from the EVOS, are unknown.

Harbor seals are an important subsistence resource. In 1985-1988, they made up 13%-27% of the subsistence foods harvested in Tatitlek and Chenega Bay. Since the EVOS, the number of seals harvested by subsistence hunters in PWS has declined by over 60%. Harbor seals interact with and are incidentally killed in commercial fisheries. Like all marine mammals, they have federal protection under the Marine Mammal Protection Act (MMPA). Because of the ongoing decline, they are currently being considered for listing as depleted under the MMPA. It is essential that current population data be available, as well as information about what may be causing the decline, so that inappropriate restrictions on human activities are not implemented.

This project is a continuation and redirection of a harbor seal restoration study that has been conducted by ADFG since 1992. The ongoing study has consisted primarily of recovery monitoring and satellite tagging of seals to determine their movements, use of haulouts, and diving and haulout behavior in PWS. The proposed 1995-1997 study will build upon previous research findings and incorporate new components to address high-priority issues regarding harbor seal recovery.

The ADFG study will have five key components: 1) Restoration Monitoring - Harbor seal numbers will be monitored during pupping and molting periods at 25 trend count sites in PWS to determine whether or not recovery is occurring; 2) Habitat Use - Seals will be instrumented with satellite tags (PTTS) in 1995 and 1996 to investigate habitat use, movements, and diving and haulout behavior; 3) Trophic Interactions - Fatty acids in blood and blubber of harbor seals and in prey species will be compared and relative frequencies matched to provide an indication of diet and to elucidate food webs in PWS; 4) Demographic Modeling - The effects of killer whale predation, subsistence harvest, and other mortality on the harbor seal population in PWS will be modelled in order to evaluate whether any of these factors may be inhibiting recovery; and 5) Disease and Genetics - Blood serum samples will be analyzed for phocine distemper, herpes virus, and other diseases that could cause health problems in the seal population. Skin samples will be used for genetic analysis to determine the relationships of PWS harbor seals to those in other parts of Alaska.

NEED FOR THE PROJECT

Because of the ongoing decline in harbor seal abundance, which was exacerbated by the EVOS, it is particularly important to understand what factors are limiting the harbor seal population. Because of the ongoing decline and the lack of recovery in the oiled areas, we cannot assume that the number of seals in oiled areas will stabilize and/or return naturally to pre-spill levels. It is necessary both to continue monitoring population trends and to identify and appropriately manage areas or resources of biological significance in order to augment recovery in any way

possible. Native residents of PWS utilize harbor seals extensively as a source of food, and have noted the scarcity of seals and the impact this has had on subsistence hunting. Commercial fisheries in PWS may face more restrictive measures regarding incidental take of harbor seals unless something can be done to understand and reverse the population decline.

The ongoing decline of harbor seals began over two decades ago in the northern Gulf of Alaska and at least a decade ago in PWS. Although periodic surveys have documented these downward trends, they have done nothing to elucidate the cause of the decline. Unless research is specifically designed and conducted to investigate the factors limiting harbor seals, it is likely that little progress will be made in understanding the decline. Similar declines have occurred in Steller sea lions (*Eumetopias jubatus*), also for unknown reasons. For both of these species, it has been suggested that changing prey availability may be responsible. This is a difficult but important topic to investigate. It will require a multidisciplinary approach that incorporates an understanding of harbor seal behavior, habitat use, and energetics with data about the distribution, abundance and biology of prey species and predators.

PROJECT DESIGN

A. Objectives

1. Monitoring: a) continue monitoring harbor seal population trends in PWS during pupping and molting in 1995 and 1996; b) recommend a monitoring schedule for 1997 and beyond; c) evaluate whether seal numbers are continuing to decline, have stabilized, or are recovering to pre-spill levels.
2. Habitat Use: a) describe hauling out and diving behavior, and by inference, feeding behavior of satellite-tagged seals in PWS; and b) describe the use of and movements between haulouts and feeding areas.
3. Trophic Interactions: a) determine individual, seasonal, and interannual differences in fatty acid composition of lipid stores in harbor seals from PWS; b) assess variation in the fatty acid composition of prey species; c) statistically determine prey items in harbor seal diets using analyses of fatty acid signatures; and d) evaluate the relative contribution of each prey type to the overall diet using measured fat content of the prey.
4. Demographic Modelling: a) model the effects of killer whale predation, the subsistence harvest, and incidental take by fisheries on the harbor seal population; and b) evaluate how these factors may impact recovery from the EVOS.

5. **Disease and Genetics:** a) conduct viral screening to determine whether disease may be causing or aggravating the harbor seal decline; b) conduct genetic analysis to determine whether PWS harbor seals constitute a genetically distinct population.

B. Methods

We are proposing two years of field study (1995 and 1996) with final data analysis and reporting to take place in year three (1997). Findings from this study will be evaluated annually and modifications in study approach will be recommended in order to incorporate recent findings from this and other PWS ecosystem studies. In addition to the five components outlined in this project description, questions about health and condition, stable isotope analyses, predation by killer whales, and prey availability will be addressed by other studies included in the Marine Mammal Ecosystem package.

1. **Monitoring:** Harbor seal abundance will be monitored by flying aerial surveys during pupping (June) and molting (late August; September). A fixed-wing aircraft will be used to fly a survey of 25 trend count sites at an altitude of 700 ft. These 25 sites have been used by ADFG for PWS harbor seal trend counts since 1983, including NRDA and Restoration studies in 1989-1994. Replicate counts will be made at each site in allow statistical analysis of trend. Methodology and observers will be the same as in 1989-1991.
2. **Habitat Use:** Satellite-linked time-depth recorders (PTTs) will be attached to 12 seals per year at locations chosen for their proximity to forage fish and oceanographic stations sampled as part of other PWS ecosystem studies. Seals will be caught by entanglement in nets placed near haulouts and PTTs will be glued to their backs with epoxy resin. Each PTT will transmit signals to polar-orbiting satellites whenever the seal is hauled out or when it surfaces for a sufficient time. Sensor information will indicate when the animal is hauled out, and how deep and for how long it dives. PTTs will be shed during the annual molt in July-August.
3. **Trophic Interactions:** Blubber samples will be taken from seals by biopsy and blood will be collected from extradural vein. Samples will be collected from all seals that are caught during tagging operations. Prey species will also be analyzed. During year one, approximately 10 species that are known to be prey of harbor seals in PWS will be sampled during two seasons. For each species, 8 individuals of the size range consumed by seals will be collected and analyzed for total fat and protein content and fatty acid composition. During year two, prey species determined to be most important in the diet will be examined in more detail. Samples will be obtained from herring and forage fish projects.

Fatty acid methyl esters will be extracted from seal blubber and prey and analyzed using temperature programmed gas liquid chromatography. Approximately 70 fatty acids and isomers can be separated and quantified in most marine lipids. Fatty acids will be used to evaluate food webs in two ways. The array of fatty acids in seal tissues will be statistically compared to fatty acids in prey species in order to quantify the relative contribution of each prey item to the overall diet. In addition, single unusual or unique components will be used to trace a specific prey. Data will be analyzed using a multivariate model called a tree regression analysis which has recently been applied and modified for fatty acid signature analysis.

4. **Demographic Modeling:** A demographic model will be developed to examine the effects of predation, harvest, and incidental take on the harbor seal population in PWS. The model will use life table data from PWS harbor seals collected by ADFG in the 1970s. Data on the subsistence harvest will be provided by ADFG's Division of Subsistence, obtained in cooperation with subsistence hunters from Chenega Bay, Tatitlek, and Cordova. Information on killer whale predation will be obtained from the proposed NMML/NMFS study on Effects of Killer Whale Predation on Injured Resources, as well as from other pertinent studies. Data on incidental take in fisheries will be obtained from NMFS.
5. **Disease and Genetics:** Viral swabs, blood serum, and skin samples will be collected from seals caught during tagging. Disease assays from swabs or serum will be conducted by a variety of laboratories specializing in these assays. Genetics analyses will be conducted by NMFS/SWFSC.

C. Schedule

This project will be conducted during 1995 and 1996, with either a recommendation for additional field studies or submission of a final report in 1997. Aerial surveys will be conducted during 7-14 days in June and August/September. Satellite tagging, and associated sampling for lipid and stable isotope analyses, genetics, and disease work will take place during late April/May and/or September. PTTs must be ordered by January of each year. Satellite data acquisition costs must be encumbered in February. Data are received monthly and preliminary analyses will begin as soon as diskettes are received. Final analyses cannot be completed until the PTTs have ceased to function. A report of field activities will be submitted in letter form within 30 days following any field activity. The principal investigator will participate in planning workshops, as scheduled by the Trustee Council, and be prepared to present findings of this study. An annual progress report will be submitted by 15 April of each year. A final report will be submitted by 30 September 1997. Results will be prepared for publication in peer-reviewed journals.

D. Technical Support

Computer programming and biometric support will be provided by project personnel at ADFG Fairbanks. Laboratory analyses of lipids, blood, and genetics samples and viral screening are budgeted for as part of this study but will be done by agencies or institutions other than ADFG.

E. Location

Aerial surveys will be conducted of 25 established trend count sites in PWS. Seal tagging and sampling will also take place in PWS. Tagging locations will be coordinated with forage fish and oceanographic studies.

PROJECT IMPLEMENTATION

This study will be conducted by ADFG, Division of Wildlife Conservation. ADFG personnel have over 20 years of experience conducting harbor seal research in PWS, including trend count surveys and studies of natural history and diet. ADFG has conducted all previous harbor seal NRDA and Restoration Monitoring and Research studies (1989-1994). Project personnel have developed the methodology for trend count surveys and for catching and tagging seals in PWS. ADFG works closely with the National Marine Mammal Laboratory/NMFS which is the agency responsible for managing harbor seals.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is a multidisciplinary, interagency undertaking. Surveys and satellite tagging will be conducted by ADFG. Lipid analyses and interpretation will be conducted at Dalhousie University. Blood chemistry analyses will be coordinated by UAF. Genetics samples will be analyzed at SWFSC/ NMFS. Demographic modelling will be done by personnel at NMML/NMFS.

This project is part of an integrated Marine Mammal Ecosystem package. Studies in this package include this project (Harbor Seal Monitoring, Habitat Use, and Trophic Interactions); Harbor Seal Condition and Health Status (UAF); Effects of Killer Whale Predation on Recovery Rates of Injured Resources (NMML); and Confirming Food Web Dependencies in the PWS Ecosystem Using Stable Isotope Tracers (UAF). In addition, this study will be closely integrated with Herring (ADFG) and Oceanographic (UAF) studies being submitted under the SEA plan and with the Forage Fish study being developed by NMFS to investigate food availability to pelagic predators. Prey samples obtained by Herring and Forage Fish studies will be analyzed as part of this study. Species to be analyzed will be chosen based on their collective importance to harbor seals, seabirds, and killer whales. Modelling efforts will incorporate and build on the results of a restoration study being conducted by the ADFG Division of Subsistence entitled Harbor Seal and Sea Otter Recovery.

ADFG is conducting studies of harbor seals in southeast Alaska and near Kodiak with funding from NOAA/NMFS. Those studies contain similar components to the PWS study and are closely coordinated to ensure that data are collected and analyzed in a similar manner. This will facilitate comparisons of data from declining populations (PWS and Kodiak) and healthy populations (southeast Alaska) of harbor seals.

FY 95 BUDGET (\$K)

Personnel	125.4
Travel	11.7
Contractual	123.1
Commodities	58.1
Equipment	1.4
Subtotal	319.7
Gen. Admin.	27.4
Total	347.1

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Restoration of Salmon Stocks of Special Importance to Native Cultures

Project Number:	95069
Restoration Category:	General Restoration (new)
Proposed By:	ADFG
Cooperating Agency:	USFS
Cost FY 95:	\$665,700
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	2 years (for this phase which targets restoration of 8 stocks; success of project will be evaluated over an additional 3 years)
Geographic Area:	Prince William Sound, Lower Kenai Peninsula, Kodiak
Injured Resource/Service:	Pink salmon and subsistence

INTRODUCTION

Pink salmon primarily spawn intertidally in Prince William Sound and to varying degrees throughout their Northern Gulf of Alaska range. Consequently eggs and pre-emergent fry were exposed to oil while they incubated in intertidal gravel following the *Exxon Valdez* oil spill (EVOS). Significant injuries were documented at the time which ultimately resulted in fewer adult returns to oiled streams, but there also appears to have been heritable genetic damage which makes successful spawning roughly twice as unlikely (up to 40% for some streams) for returning adults. The Alaska Department of Fish and Game and the United States Forest Service conducted stream rehabilitation surveys (Project 93063) in order to determine which methods of habitat or stock manipulation would be appropriate for particular streams. From these developed project 94139, Salmon Instream Habitat and Stock Restoration, which began to implement the findings of 94063. While restoration of impacted stocks and sport and commercial fishing services were considered, subsistence uses of particular stocks were not given major consideration. The currently proposed project is designed to identify stocks of particular interest to subsistence users and, where needed, apply appropriate instream habitat and stock restoration techniques using native skilled craftsmen and laborers to the extent possible under the guidance of USFS and ADFG biologists. As well as instream techniques, incubation of stocks at hatcheries to improve egg to fry survival and other hatchery involvement will be among techniques considered.

NEED FOR THE PROJECT

Many subsistence foods were impacted by the EVOS and users have been forced to substitute subsistence caught foods with commercially obtained processed foods. While some resources are recovering, use of subsistence foods has not returned to a pre-spill level and will not until subsistence resources have returned to pre-spill and appear to be free from tainting by petroleum hydrocarbons. In order to return to a more traditional lifestyle, native users have suggested a need to restore and enhance stocks of salmon returning to streams of particular interest to them. Because this is a need expressed by them and the stocks provided subsistence foods directly to them, they are interested in participating in the efforts to restore these stocks.

PROJECT DESIGN**A. Objectives**

Restore and enhance salmon stocks identified by native users as depressed and of value to their subsistence life style. A target of approximately eight stocks are to be affected by this project in 1995.

B. Methods

Specific techniques are dependent upon methods deemed most likely to succeed and cost effective for particular streams. The restoration options include but are not limited to egg incubation boxes, fish barrier bypasses, spawning channels, incubation of eggs and early juvenile rearing at hatcheries with planting of juveniles in the stream of origin, capture of emergent fry at streams and short term rearing in netpens off the stream mouths. Cost benefit ratios have been conducted somewhat differently by USFS and ADFG in the past. These methods will be modified to include subsistence values.

C. Schedule

Date	Action
Nov. 1994	Request list of candidate streams from native subsistence users.
Dec. 1994	Assess appropriate restoration/enhancement techniques for up to eight streams/stocks. Begin NEPA process for those streams with known appropriate techniques.
May 1995	Complete NEPA for streams with known appropriate restoration/enhancements. Initiate requests for proposals for restoration/enhancement of these streams/stocks
June 1995	Award contracts for restoration/enhancement.
July-Sept. 1995	Obtain permits, conduct restoration/enhancement actions.
Jan.-Sept. 1995	Conduct surveys of streams where appropriate restoration/enhancement techniques have not been determined.
Oct. 1995	Initiate NEPA for streams surveyed in 1995.
Dec. 1995	Complete NEPA. Initiate requests for proposals for restoration/enhancement of these streams/stocks.
Jan. 1996	Award contracts for restoration/enhancement.
Feb.-May 1996	Obtain permits.
June-Sept. 1996	Conduct restoration/enhancement actions.
1996-1998	Evaluate success of project.

D. Technical Support

None anticipated at this time.

E. Location

Prince William Sound, Lower Kenai Peninsula, Kodiak

PROJECT IMPLEMENTATION

ADFG and US Forest Service will seek candidate streams, assess the appropriateness of techniques, conduct RFP's, award contracts and assess the success of the project at individual streams. ADFG and US Forest Service may conduct surveys of streams for which appropriate restoration/enhancement techniques have not been previously determined or these agencies may contract out this work. NEPA compliance will be conducted by ADFG and US Forest Service. Contracts will be awarded for actual restoration/enhancement actions. It is expected that native organizations will be employed for instream habitat manipulation and private non-profit corporations will provide any hatchery services required.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will be coordinated with other 1995 pink salmon and subsistence projects.

FY 1995 BUDGET (\$K):

Personnel	150.0
Travel	16.0
Contractual	400.0
Commodities	40.0
Equipment	16.0
Subtotal	622.0
Gen. Admin.	43.7
Total	665.7

Herring Reproductive Impairment

Project Number:	95074
Restoration Category:	Research (new)
Proposed By:	National Marine Fisheries Service
Lead Trustee Agency:	NOAA
Cooperating Agency:	ADFG
Cost FY 95:	\$407,200
Cost FY 96:	\$119,200
Total Cost:	\$526,400
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring

INTRODUCTION

Herring stock in Prince William Sound (PWS) may have been reproductively impaired by the 1989 *Exxon Valdez* oil spill, and it is feared that continuing long-lasting effects could hamper restoration of the stocks that have crashed since the spill. Most or all of the life stages of herring may have been exposed to oil after the 1989 *Exxon Valdez* oil spill in PWS. Significant histopathological damage was observed in adults collected in oiled areas in 1989 and 1990 (ADFG), and over 40% of the spawning areas were oiled (ADFG). Exposure of herring eggs to petroleum hydrocarbon concentrations frequently results in abnormal larvae with poor survival potential. In the pectoral fins of herring embryos exposed to oil, anaphase aberrations was elevated, giving some credence to the hypothesis that long term genetic damage was possible to the germ line. Because year-class strength is heavily influenced by survival of herring larvae, contamination of pre-spawn adults, eggs, or larvae by petroleum hydrocarbons may have an adverse impact on herring populations. Long term effects are possible and unknown.

The primary goal of the study is to determine if herring reproduction can be impaired by exposure to oil; a combination of controlled laboratory exposures and viability measurements from herring in the field will be used. In year one (FY 94), our goal was to determine if exposure of pre-spawning adults to oil would result in genetically impaired larvae with reduced survival potential. In year two (FY 95), the laboratory oil exposures will be extended to eggs and larvae, with similar measurements of genetically impaired larvae. This will allow direct comparison of impacts between adult, egg, and larval stages. Data will be used to infer what the relative effects the *Exxon Valdez* oil spill were on adult and early life stages of herring in PWS. In addition, a field component of the study will measure the current status of herring reproduction at several locations in PWS by age class. Spawn from these herring will be returned to the lab and incubated in a stable and common environment for determination of hatching success and abnormality rates for each age class and spawning location.

The field component in FY 95 will be integrated with the two other herring components -- the age/weight/length analyses by ADFG, and the disease sampling by ADFG or independent contractor. All of the samples for each component will come from the same group of fish sampled at a spawning site.

NEED FOR THE PROJECT

Five years after the *Exxon Valdez* oil spill, questions concerning the impact of oil persist, as well as questions about the recovery potential of herring. There is evidence that exposure to oil may have caused long term genetic damage in herring; this issue has been identified as a critical by the *Exxon Valdez* Oil Spill Trustee Council. In years after the spill, recruitment to the fishable stock has been unexpectedly low, and disease incidence has been unexpectedly high. Of principal concern is whether the herring population is reproductively impaired as a result of exposure to oil. Evaluation of the extent of reproductive impairment should be possible from the results of this study. If impairment has occurred, adjustment in the management of the herring fishery in PWS may be necessary.

PROJECT DESIGN

A. Objectives

1. Determine if exposure of herring eggs and larvae causes genetic injury. This is a continuation of the three year research proposal initially funded in 1994. From estimates of somatic genetic damage, we will infer the possibility that exposure of herring to oil can cause genetic damage that is transmissible to subsequent generations. It is not practical to measure germ line damage directly in the laboratory because it is not possible to rear herring from eggs to maturity. In 1994, oil was exposed to pre-spawning adults and genetic aberrations in eggs and larvae were measured. In 1995, oil will be exposed to eggs and larvae, and genetic aberrations will be measured. Aberration rates will be compared across exposure doses and life stage exposed.

2. Survey herring in PWS for reproductive impairment by measuring larval viability by location and age class. Herring reproduction may be impaired as a result of past oil exposures at one or more life stages. In 1995, we will measure herring reproduction success from several age classes collected from several sites in PWS. Some of the age classes were exposed to oil, but post 1990 year classes were not. Spawn will be returned to the lab and reared until hatch to determine larval viability and abnormality rates.

B. Methods

1. Adult herring will be artificially spawned onto glass slides (identified by fish) or substrate contaminated with oil. Eggs will be exposed to two types of treatments - oil in water (as in FY94) and to oil contaminated substrate. One series of treatments will consist of four oil doses plus a control. For larval exposures, eggs will be incubated in clean water, and resultant larvae will be exposed to a series of doses. Chromosomal aberration rates will be the primary measurement. The number of mitoses per fin and chromosomal (anaphase) aberrations will be assessed from subsets of larvae at the point of yolk resorption. Data will also be collected to determine graded severity indices (morphological defects), condition of interphase cells, and number of degenerating cells. Several secondary parameters will be observed periodically to determine fertility, hatching, death, and larval viability. Genetic observations will be completed after preservation.
2. Herring will be collected from multiple locations throughout PWS, aged, and crossed. Additional herring will be similarly crossed from a control location, Sitka Sound. The goal is to obtain 25 fish from each age class at each location. The eggs will be incubated in individual containers at the Auke Bay Laboratory (ABL) until hatch. Larval viability will be judged at hatch for each female, age class, and location. Hatch timing, percent fertile, morphological abnormalities, and egg survival will also be recorded. Researchers from ABL will work closely with ADF&G to collect fish; age, length, weight, and VHN samples can be collected at the same time, thus integrating state and federal research objectives.

C. Schedule

1994 brood year:	Mar 1995	Finish analyses and reports
1995 brood year:	Jan-Jun 1995	Laboratory exposures
	Feb-Jun 1995	Reproductive impairment survey in PWS
	Jul-Nov 1995	Chemical and contract analyses
	Dec 1995-Apr 1996	Data analysis and final report

D. Technical Support

All egg and larval culturing and chemical analyses will be conducted at ABL. Chemists at ABL will participate in oil dosing and analysis. Computer services, data archiving, and GIS mapping are all services available in-house at the Auke Bay Laboratory. Herring researchers at ABL will work closely with ADFG to obtain herring and spawn in PWS, so that age, length, weight, and disease sampling are all from the same spawning sites. We will ask ADFG to age all of the adult herring spawned. Analysis of genetic aberrations will be contracted out.

E. Location

Herring impairment samples will be collected in PWS and at Sitka (control site). All lab exposures and rearing will be at ABL.

PROJECT IMPLEMENTATION

Project would be implemented by NOAA/NMFS/Auke Bay Laboratory with interagency cooperation with ADFG and the SEA plan. Researchers at the Auke Bay Laboratory are uniquely suited to complete this project because of their expertise and knowledge in culture and maintenance of adult, egg, and larval herring, their history of oil related research (including herring), continuity of similar research completed in 1994, and hydrocarbon analytical facilities.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is an integral component of the suite of herring studies in the SEA plan. Reproductive impairment sample collection will be integrated with herring disease and spawn deposition research.

FY 95 BUDGET (\$K)

Personnel	243.2
Travel	20.5
Contractual	64.0
Commodities	33.5
Equipment	5.0
Subtotal	366.2
Gen. Admin.	41.0
Total	407.2

Relation of Mussel Population Structure to the Recovery of Injured Nearshore Vertebrate Predators

Project Number:	95075
Restoration Category:	Research (new)
Proposed By:	NOAA
Cost FY 95:	\$197,500
Cost FY 96:	\$116,600
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sea otter, harlequin duck, intertidal organisms

INTRODUCTION

The blue mussel, *Mytilus trossulus*, is a dominant member of intertidal communities in Prince William Sound where mussel populations were injured by the *Exxon Valdez* oil spill (EVOS) to the extent that mussels continue to limit the recovery of a few key predator species. Sea otters (*Enhydra lutris*) feed on mussels and are not considered to have recovered from the EVOS. There are two possible reasons for the continuing impacts: (1) heavy oil contamination of some mussel beds is exerting a direct toxicological effect on sea otters; (2) oil pollution has had an impact on mussel abundance and population structure. Previous studies have confirmed the continuing oil-contamination of some mussel beds, but those studies have not examined mussel population structure, mussel growth or biomass distribution. Food limitation and changes in benthic community structure are important factors influencing the recovery of some injured resources (e.g., sea otters). Because mussels represent a major part of the diet of young sea otters and females with large dependent pups, recovery of sea otters may be constrained by reduced prey abundance or biomass. Mussels provide spatial complexity, interact strongly with other occupiers of space and act as prey for a broad range of invertebrate and vertebrate predators. Changes in mussel abundance often result in major changes in intertidal community structure which could, in turn, affect recovery of sea otters that forage in the intertidal region.

This project will coordinate with the mussel bed restoration study (by occupying some of the same sites and sharing chemistry data where appropriate). This project will measure the abundance, size distribution and growth of mussels in populations at oiled and unoiled locations and relate the measurements to known predator densities.

NEED FOR THE PROJECT

This project is designed to meet the needs of NVP and where appropriate bridge the gap between NVP and the mussel bed restoration project. The project will determine the relative influence of mussel contamination and food limitation on the recovery of injured vertebrate species. This information will benefit those researchers monitoring the recovery of sea otters.

PROJECT DESIGN

This project will address NVP hypothesis H_{01} : Prey populations in areas where vertebrate predator densities were reduced by oil exposure do not differ from areas where predator populations were not reduced.

A. Objectives

1. Determine the distribution and abundance of *Mytilus* along segments of coast in Prince William Sound with and without oiled mussel beds and under different densities of vertebrate predators.
2. Compare the size structure of populations of *Mytilus* in oiled vs unoiled habitats and under low vs high vertebrate predation pressure in Prince William Sound.
3. Compare concentrations of hydrocarbons in tissues of *Mytilus* in oiled and unoiled habitats. (This objective would supplement the chemical analyses of the mussel bed restoration project where needed.)
4. Measure growth of *Mytilus* in oiled and unoiled habitats and under low and high vertebrate predation pressure.

B. Methods

The distribution and abundance of mussels will be determined over lengths of coastline to be determined by the vertebrate predator subgroup. Within a particular segment of coast, mussel abundance will be estimated using stratified random sampling with proportional allocation. Mussel densities will be estimated using 1/16 m² quadrats. Each length of shore will be divided into segments of bedrock, unconsolidated coarse substrate and unconsolidated fine substrate. Sample size will depend on mussel density. Mussels in the quadrats will be counted and maximum shell length will be measured. Mussel tissues will be dried and weighed on a

precision balance. Individual mussels from each substrate type in each segment of coast and in each oiled mussel bed will be tagged with calcein to measure growth. Mussels will be tagged and released at intervals of three months. Tagged individuals will be retrieved and growth measured at the end of each three month period.

Mussels will be collected for tissue hydrocarbon analysis immediately adjacent to a subset of the randomly placed quadrats used for density estimates. Three composite samples of mussels will be collected from oiled and unoled mussel beds along each stretch of coastline. Samples will be placed in coolers with ice immediately after collection and will be frozen within an hour. Appropriate blanks will be collected at each site. Chain of custody procedures will be followed after collection of all hydrocarbon samples.

C. Schedule

The leader of this project will participate in all planning meetings. Mussel sampling will be conducted in May, July and September 1995. Mussels will be tagged for growth in May, July, September and November 1995 and February and April 1996. An annual report will be completed by March 1996 to be incorporated in the annual synthesis report by April 1996. Laboratory and chemical analyses will be completed by August 1996. Data compilation and computer analysis will be completed by October 1996. A final report will be completed by December 1996.

D. Technical Support

The project will require technical support in hydrocarbon chemistry (UV spectrophotometry and gas chromatography/mass spectrometry). The chemistry will be performed at the Auke Bay Laboratory. The cost of the hydrocarbon chemistry is included in the project budget. Vessel charters will be required to support the field sampling.

E. Location

This project will be undertaken at a minimum of four segments of coastline in Prince William Sound (two in an area of low vertebrate predator density and two in an area of high vertebrate predator density). Potential geographical areas of study include (1) northern Knight and Naked Islands (an area of lowest sea otter density), (2) southern Knight Island (an area of low sea otter density), and (3) northwest Montague Island (an area of higher sea otter density). Each coastal segment will include at least one oiled mussel bed. Each substrate type will be sampled in each coastal segment. The exact coastal segments sampled will be selected in consultation with the vertebrate predator subgroup.

PROJECT IMPLEMENTATION

This project will be implemented by the Auke Bay Laboratory under management by the National Biological Survey. The Auke Bay Laboratory is currently participating in the Mussel Bed Restoration and Monitoring Project and therefore information on site selection and existing data on recently studied mussel beds in Prince William Sound should be readily available to the present project. The Auke Bay Laboratory has unique expertise in and extensive experience with mussel beds in Prince William Sound.

COORDINATION OF INTEGRATED RESEARCH EFFORT

It will coordinate closely with two ongoing restoration projects, the Mussel Bed Restoration and Monitoring Project and the Hydrocarbon Data Analysis and Interpretation Project. Sampling by the present project will be closely coordinated with the Mussel Bed Restoration and Monitoring Project occupying the same sites and sharing chemical analyses where appropriate.

FY 95 BUDGET (\$K)

Personnel	94.0
Travel	20.0
Contractual	48.0
Commodities	18.0
Equipment	0.0
Subtotal	180.0
Gen. Admin.	17.5
Total	197.5

Effects of Oiled Incubation Substrate on Survival and Straying of Wild Pink Salmon

Project Number:	95076
Restoration Category:	Research (new)
Proposed By:	National Marine Fisheries Service
Lead Trustee Agency:	NOAA
Cost FY 95:	\$179,900
Cost FY 96:	\$310,900 (includes \$108,000 for data analysis and report writing)
Total Cost:	Unknown
Duration:	6 years
Geographic Area:	Little Port Walter, Baranof Island, Alaska
Injured Resource/Service:	Pink salmon, commercial fishing

INTRODUCTION

The toxicological effects of the *Exxon Valdez* oil spill on pink salmon in Prince William Sound (PWS) remain a high priority research issue. Since 1991, the pink salmon returns to PWS have declined precipitously. Prior NRDA research projects have documented reduced survival of pink salmon embryos exposed to oil during incubation, and have suggested that the damage may be heritable, thus impacting subsequent generations of fish. High straying rates for pink salmon have also been observed in PWS since the oil spill: straying rates of wild pink salmon returning to PWS in 1991 ranged from 8 to 54% in three streams in oiled locations, and from 11 to 51% in three streams in non-oiled locations.

The effect of oil exposure on straying rates of pink salmon is unknown. Increased straying rates may result from disruption of the imprinting process caused by incubation in oiled substrate. Highly conserved characters such as emergence timing are disrupted by incubation in oiled substrate. A confounding factor in the previous NRDA research on straying was that even fish from non-oiled streams were probably exposed to oil during their saltwater migrations. In addition, too few replicates were used to evaluate differences in straying, given the observed variation. Pink salmon in this proposed study will be exposed to oil only during the incubation phase, and then released to migrate to the Gulf of Alaska through the non-oiled waters of southeast Alaska. The effects of exposure on straying rates will be determined from the

returning adults. The study will also provide information that either validates the high straying rates documented for PWS pink salmon in NRDA F/S Study No. 3778778, or that identifies factors unrelated to oiling that could have caused the observed straying.

Whether incubation in oiled substrate can cause genetic damage is also being examined, and this proposed study will examine the potential for further genetic damage to populations resulting from introgression with straying salmon. This proposed study will complement Restoration Study No. 94191 by providing estimates of marine survival for wild pink salmon exposed to different levels of oil in the incubation substrate and by providing gametes for further analysis of the genetic damage hypothesis.

NEED FOR THE PROJECT

Reliable estimates of the straying rate and heritable damage of wild pink salmon are essential for the effective restoration of the damaged pink salmon population in PWS. Since the *Exxon Valdez* oil spill, returns of wild pink salmon to PWS have been poor, the full extent of injury is still unknown, and the exact mechanism of injury is unclear. Stock separation information to help management protection of damaged stocks has been identified as a high priority general restoration technique, but without knowledge of straying rate, stock separation information is of limited value. Little is known about the straying rate of wild pink salmon even without the confounding effect of oil in the environment. If straying rates as high as 50% occur without any influence from oil, then restoration of damaged pink salmon runs can be expected to occur naturally through recolonization from healthy stream systems. However, if the presence of oil increases straying, fisheries managers must be aware that genetic damage hypothesized to occur as a result of incubation in oiled substrate may be passed on to pink salmon in streams originally not oiled by the *Exxon Valdez*. Thus, damage to wild salmon populations may be more widespread and persistent than previously conceived. Documenting a greater degree of damage could allow additional damage claims under the civil settlement.

The degree of straying of wild pink salmon is also an important facet in the current controversy involving the effects of large-scale enhancement on wild pink salmon populations in PWS. If the high straying rates for wild fish observed in NRDA F/S Study No. 3 are representative of normal rates, then genetic structure of the populations in the region should be relatively homogeneous and large-scale mixing of wild stocks and the hatchery stocks derived from them should be of minor concern. If, however, oil exposure or hatchery practices have artificially increased the straying rates, and rates are normally low, then the genetic diversity among and within wild stocks may be in jeopardy from increased straying.

PROJECT DESIGN

This project has been designed with two components. Component A will examine the effect of oil exposure during embryonic development on marine survival, straying, and gamete viability. Comparisons of straying rates in Component A are valid for dosage response and can stand alone as an experiment, but estimation of actual straying rates is confounded by other factors. Component B evaluates the influence of factors such as the incubation environment, stock, and tagging, on straying. Component B greatly strengthens the evaluation of straying by controlling for these other factors, and is extremely cost-effective because of the resources necessary for Component A: Component B represents approximately 10-15% of the annual cost of the project.

A. Objectives

The objectives of Component A are to expose pink salmon to oil during egg incubation in a simulated intertidal environment, release the fry into salt water, and determine the effect on: 1) straying, 2) marine survival, and 3) gamete viability of returning adults. The objectives of Component B are to determine the influences on straying behavior of 1) incubation environment, 2) stock, and 3) coded-wire tagging.

B. Methods

Component A - Pink salmon eggs from two brood years will be incubated in a controlled simulation of oiled intertidal habitat which occurred in Prince William Sound after the *Exxon Valdez* oil spill. Pink salmon gametes will be collected in the fall of 1995 and 1996 from Lover's Cove Creek, Big Port Walter, Baranof Island, southeast Alaska and transported to the nearby NMFS research station at Little Port Walter (LPW). The fertilized eggs will be incubated at LPW under one of four treatments of oiled gravel: control, low oil, medium oil, and high oil. Eggs will be exposed to salt water for 4-hour intervals every 12 hours to simulate an intertidal environment. Dosing levels will be established by analyzing hydrocarbon concentrations in incubator effluent, substrate, and fish tissue with gas chromatograph and mass spectroscopy (GC/MS) at each major developmental stage: eyeing, hatching, and emergence. For each treatment group, survival to eyeing and emergence, and size at emergence and release will be determined. In the spring of 1996 and 1997, a total of 120,000 pink salmon fry (30,000 per treatment) will be coded-wire tagged (CWT, 3 code lots per treatment) each year before being released into salt water at LPW. An analysis of power indicates 80% certainty that differences in straying of 3-5% between treatments will be detected 95% of the time.

Marine survival and straying rates for the different treatment groups will be determined from the tagged adult pink salmon returning to spawn at LPW and the surrounding area in the fall of 1997 and 1998. Weirs will be set up across Sashin Creek (LPW) and Lover's Cove Creek to collect the adult fish. Additionally, tagged pink salmon will be collected from the Port Armstrong hatchery south of LPW and from streams on the eastern shore of Baranof Island within 20 km north and south of LPW.

Gamete viability and offspring survival to emergence will be determined for each treatment group in each brood year. Gametes from surviving adult pink salmon from each treatment group will be collected, crossed and incubated in a clean environment. Because incubation for the second generation will occur in a clean environment, differences in survival, size, or number of defective individuals can be attributed to oiling effects upon the first generation.

Component B - Pink salmon gametes will be collected from Sashin Creek concurrently with the egg-takes from Lovers' Cove Creek. The Sashin Creek pink salmon population is composed predominately of upstream spawners, while the Lovers' Cove Creek stock is composed predominately of intertidal spawners. Gametes from both stocks will be incubated in both the simulated intertidal environment used for Component A, and in freshwater only (to simulate an upstream environment). For each treatment group, 30,000 fry will be marked with CWTs (3 code lots per treatment). This requires an additional 90,000 fry to be tagged beyond Component A, since the control group in Component A doubles as a treatment in this experiment. In addition to these groups, wild fry emigrating from Sashin Creek and Lovers' Cove Creek in 1996 and 1997 will be captured, marked, and released. From each stream, 30,000 fry will be tagged with CWTs (3 code lots) and 30,000 fry will receive a ventral fin clip.

Tagged and fin-clipped adults from Component B releases will be recovered with no additional effort or resources than those necessary for Component A. Straying rates from the release groups in Component B will be compared to determine the effects on straying of: 1) incubation environment (freshwater vs. intertidal); 2) population origin (upstream population vs. intertidal population); 3) coded-wire tagging (ventral fin-clips vs. CWT wild fry); and 4) hatchery treatment (artificially spawned, and incubated fry vs. wild fry).

C. Schedule

<u>Date</u>	<u>Activity</u>
1/95	Initiate procurements, hiring, contracts needed for project
6/95	Reconfigure LPW wetlab for experimental design
7/95	Set up incubators for 1995 brood
8/95	Oil gravel, spawn pink salmon (1995 brood)
9/95-3/96	Incubation, 44 GC/MS samples collected
3/96	Install weirs for collecting 1995 brood wild fry
4/96	Tagging and release of 1995 brood hatchery and wild fry
4/96	Annual Report
6/96	Contract deliverable, 44 GC/MS samples from 1995 brood
7/96	Set up incubators for 1996 brood
8/96	Oil gravel, spawn pink salmon (1996 brood)
9/96-3/97	Incubation, 44 GC/MS samples collected (1996 Brood)
4/97	Tagging and release of 1996 brood hatchery and wild fry
4/97	Annual Report
6/97	Contract deliverable, 44 GC/MS samples from 1995 brood
7/97	Install weirs for collecting returning 1995BY adults
8-9/97	Recovery and spawning of returning adults (95 brood)

	Contract deliverable, Port Armstrong Hatchery
9/97-3/98	Incubation of gametes from returning adults
4/98	Annual report
7/98	Install weirs for collecting returning 1996BY adults
8-9/98	Recovery and spawning of returning adults (96 brood)
	Contract deliverable, Port Armstrong Hatchery
9/98-3/99	Incubation of gametes from returning adults
4/99	Annual report
9/99	Final report

D. Technical Support

A biometrician will ensure that the study design provides a reasonable chance of reaching statistically valid conclusions. A chemist will establish a dosing protocol, determine hydrocarbon concentrations, and evaluate results of hydrocarbon analysis. The US Forest Service will provide use of a cabin at Lover's Cove Creek. Computer services, data archiving, tagging equipment, incubation facilities, vessel support, and a weir at Sashin Creek will be provided by the Auke Bay Laboratory.

E. Location

Gametes will be collected from Lover's Cove Creek and Sashin Creek, Baranof Island, southeast Alaska. Eggs will be incubated, and pink salmon fry will be tagged at the NMFS research station at Little Port Walter (LPW), located near the mouth of Sashin Creek, 10 km from Lover's Cove Creek. Returning adult pink salmon will be recovered from streams on the east coast of Baranof Island within 50 km of LPW.

PROJECT IMPLEMENTATION

The NMFS, Auke Bay Laboratory will implement this project. The NMFS will provide use of the research station at LPW as a base for the proposed fieldwork. This station will provide housing for project personnel, a wet lab for egg incubation, a weir across Sashin Creek for recovery of adult pink salmon, microscopes for the decoding of CWTs, and facilities for the spawning of adult pink salmon. The Auke Bay Laboratory will provide three tagging machines, vessel support, and computer services. The GC/MS samples will be analyzed under contract with the Auke Bay Laboratory. The Port Armstrong Hatchery will be contracted to provide any returning adult pink salmon that have strayed to this facility. Materials and personnel will be transported to and from LPW via the NOAA vessel *R/V John N. Cobb* and air taxi charters.

In addition to all the services mentioned above, the Auke Bay Laboratory has the technical expertise needed to implement this project. The principle investigator and each co-investigator have been involved with the NRDA process since the *Exxon Valdez* first ran aground on Bligh Reef in 1989.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Research by NMFS on effects of oil exposure to pink salmon has been closely coordinated with concurrent research efforts by ADFG and UAF. This project directly complements Restoration Study No. 94191 and will be fully coordinated with its continuation.

FY 95 BUDGET (\$K)

Personnel	76.1
Travel	5.8
Contractual	5.8
Commodities	56.4
Equipment	24.0
Subtotal	168.1
Gen. Admin.	11.8
Total	179.9

Coastal Habitat Intertidal Monitoring and Experimental Design Verification

Project Number:	95086A
Restoration Category:	Monitoring (continuation of 94086)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cost FY 95:	\$892,600
Cost FY 96:	\$1,373,100
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Prince William Sound (FY 95 and FY 97) Cook Inlet-Kenai Peninsula (FY 96 and FY 98) Kodiak-Alaska Peninsula (FY 96 and FY 98)
Injured Resource/Service:	Intertidal organisms

INTRODUCTION

The Coastal Habitat Injury Assessment Study (CHIA) was designed to measure ecosystem effects of the EVOS and cleanup on the nearshore community. The study encompassed Prince William Sound (PWS), Cook Inlet-Kenai Peninsula (CIK) and Kodiak-Alaska Peninsula (KAP). The study design allowed inductive statistical inferences of damage to the entire universe of oiled habitats through random selection of sites within habitat categories. Results of these studies can be applied to the damage assessment in higher trophic levels.

At the conclusion of the 1991 field season, several species of algae and invertebrates still showed significant damage to their populations. For most of these populations the recovery status is unknown. This study proposes to revisit the original CHIA sites and assess the recovery rate of damaged species. Percent cover, abundance, biomass, and density of key species will be quantified in all habitats. Recovery will have occurred when community composition, population abundance of component species, and ecosystem functions and services in each injured intertidal habitat have returned to levels that are found on matched, unoiled reference sites.

The second component in this proposal is to validate the After Control-Impact Pairs (ACIP) design employed by the CHIA study. Matched sets of non-oiled sites will be selected using procedures established for the CHIA project. These sites will be monitored and the data evaluated using the same procedures used by the CHIA study.

NEED FOR THE PROJECT

Coastal Habitat Monitoring

This proposed project addresses the explicit need articulated in the "Invitation to Submit Restoration Projects for Fiscal Year 1995" to monitor the injured intertidal resources. Intertidal communities were subjected to the most severe impacts of the spill and subsequent cleanup operations. The intertidal zone is not only a very productive and diverse ecosystem, but it serves as an interface between marine and terrestrial organisms. Algae form a major part of the ecosystem structure, providing protective habitat and forage for many fish and invertebrate species. In turn, birds and otters prey on these fish and invertebrates. Understanding the effects of the EVOS on the intertidal is critical in learning the extent of injury and the recovery rate of the effected areas.

Intensive sampling and research during three summers (1989-1991) show that the EVOS and subsequent cleanup had serious and long lasting effects on intertidal algae. Results generally showed lower percent cover and biomass of algal species (especially the perennial *Fucus*) on oiled sites compared to reference sites and there was a corresponding increase in the amount of bare rock at the oiled sites. In addition, *Fucus* plants in oiled sites were not as reproductive as those in reference sites and had higher levels of epiphyte infestation. Other algae had varying responses to the oiling, with significant differences detected for some species through 1991. However, each tidal elevation zone, each habitat, and each area had different patterns.

Analyses of intertidal invertebrate abundance and biomass revealed differences between oiled and control sites for several major taxa. These were the grazers *Tectura persona*, *Littorina sitkana*, and *L. scutulata*, the barnacles *Chthamalus dalli* *Balanus glandula* and *Semibalanus balanoides* and the mussel *Mytilus*; amphipods, and oligochaetes. Differences varied between regions and habitat types. Recovery of sheltered and exposed rocky invertebrate communities was proceeding in some areas based on comparisons of significant differences between oiled and unoled sites. Coarse textured and estuarine invertebrate communities had not fully recovered as of the last observation in 1991.

The intertidal fish populations, which are important forage species for the river otter and some avian species, were altered in oiled sites in 1990, followed by some recovery in 1991 within PWS sites. Density and biomass of intertidal fishes were less at reference sites in all three habitat types; exposed rocky, sheltered rocky, and coarse textured, during 1990. In 1991 some recovery occurred in sheltered and exposed rocky habitats but not at coarse textured sites. In sheltered and exposed rocky habitats, oiled and reference sites density and biomass increased between 1990 and 1991, but the increases were much greater at oiled sites than at reference sites.

Because the intertidal ecosystems still showed damage in 1991, the recovery status of the intertidal is not known. This project will monitor the status of the intertidal at previously visited sites. All sites will be revisited twice over a four year period to determine if population structures of damaged species have returned to pre-spill levels and have stabilized.

Experimental Design Verification

The experimental design used in the Coastal Habitat Injury Assessment program has potential flaws, in that there may be intrinsic differences between the oiled and reference sites, even without oiling and/or cleanup. This problem has been recognized in the "Invitation to Submit Restoration Proposals". Accordingly, we have devised a scheme to verify the experimental design by monitoring matched, non-oiled sites.

The optimal design for environmental impact monitoring includes sampling both before and after a disturbance event, at pairs of impacted and reference sites. This process is a BACIP (Before-After, Control-Impact Pairs) design. Very few of the current studies of the effects of the EVOS have been able to use this design due to the lack of pre-spill data. Instead, we have relied on sampling at pairs of oiled and reference sites after the spill to infer injury to biological resources in coastal habitats. This process is the ACIP (After Control-Impact Pairs) Design. Correct interpretation of the results produced from this design are based on the assumption that oiled and reference sites would not have differed if there an oil spill had not occurred.

There are resources within both the subtidal and intertidal habitats that have shown consistent differences among oiled and control sites using the ACIP design. For example, percent cover by *Fucus* in the mid intertidal in Prince William Sound has been consistently higher at reference than at oiled sites, and *Musculus* density on eelgrass in Prince William Sound has been consistently higher at oiled sites. Without pre-spill data, it is difficult to establish whether these differences represent long term impacts of the spill, or whether they represent inherent differences among sites. It may be that the predominant wind and current conditions within Prince William Sound that were responsible for bringing oil to specific beaches were also responsible for bringing higher concentrations of *Musculus* larvae to those same beaches.

There are essentially two ways to address this issue. First, long term monitoring of resources could be conducted to determine if the resources at oiled and reference sites "converge" after some period. This approach suffers from that fact that convergence may take very long to occur, or may never occur if some alternate stable state has been achieved after the spill. In the shorter term, agencies are faced with making decisions regarding possible restoration of supposedly injured resources. A second approach is to conduct an independent test of our ability to match oiled and control sites, and to demonstrate that the site selection process produced no biases that may have resulted in inherent differences among oiled and control pairs.

Verifying the process by which matched pairs are selected also has much larger implications with respect to monitoring programs that may be used to evaluate impacts of future oil spills as well as other disturbances. The uncertain time and location of oil spill beach impact makes it extremely difficult to obtain the appropriate "pre-spill" data at both impacted and reference sites. Costly "baseline" monitoring programs often result in data that are largely unusable for evaluating injuries. Evaluation of injuries from spills usually relies on sampling conducted only after the spill. The establishment of *a priori* criteria for the selection of oiled and control sites, and the *a priori* verification that this selection process does not produce biases in oiled-control comparisons, would be very useful in supporting inferences made from future post-spill surveys. In addition, establishment and verification of *a priori* site selection criteria, could prove much more useful, and much more cost effective than baseline monitoring studies.

PROJECT DESIGN

A. Objectives

General Objectives

1. To determine whether intertidal habitats still show damage, by conducting a comprehensive monitoring program of intertidal communities in the areas impacted by the EVOS, using the matched paired sites monitored during the CHIA study.
2. To determine if previously used site selection criteria may have resulted in biases that could lead to inherent differences among oiled and control sites that were unrelated to oiling.
3. To establish criteria for the unbiased selection of oiled and control site pairs to be used in assessing injury from future oil spills or other disturbances.

Specific Objectives

1. To monitor the original PWS CHIA study sites in sheltered rocky, exposed rocky, coarse textured, and estuarine habitats. Collect data on algal percent cover, densities of damaged invertebrate species, and densities of intertidal fish. Specific questions that will be addressed include:
 - a. Have algal, invertebrate, and fish species that showed damage in PWS in 1991 recovered? If not, to what degree has recovery occurred?

- b. What habitat variables seem to affect PWS populations of algae, invertebrates, and intertidal fish?
 - c. Was the increase in density and biomass of intertidal fish at PWS oiled sheltered and exposed rocky habitats due to recovery or interannual variability?
2. To select new sites within the sheltered rocky and coarse textured habitats in PWS for testing the ACIP stratified random sampling design. Sites will be selected with the same protocol used to select the final CHIA sites.
3. To monitor the new sites from the sheltered rocky and coarse textured habitats with the same methods used in the original sites.

B. Methods

CHIA Site Monitoring

The original matched pairs in the PWS region on sheltered rocky, exposed rocky, coarse textured, and estuarine habitats will be sampled, for a total of 28 sites. The sampling efforts for this monitoring study will focus on non-destructive measurements of intertidal algae percent covers and abundances of grazers, primary space competitors, and invertebrates and fish predators. In addition, on coarse textured and estuarine sites, some infaunal sampling will occur as those organisms showed clear statistical differences through 1991. Quadrats are located along each of six vertical transects at the first, second, and third meters of vertical drop (MVDs) from the mean high water (MHW) line. For some measurements, additional transects will be laid out, i.e. for line transects as described below.

1. **Methods for Algal Sampling**
Percent cover of benthic algae will be determined on all undisturbed quadrats using the point-contact method developed by the CHIA studies. In addition, we will perform estimations of percent cover of understory ("turf") algae and characterize the substrate at each quadrat. Specific measurements will be made on randomly selected *Fucus* plants in each MVD at each site. Measurements on *Fucus* will include plant density, size frequency distribution, degree and type of epiphytism, and reproductivity.
2. **Methods for Invertebrate Sampling**
Direct counts will be made of epifaunal organisms within original undisturbed quadrats. Within a semi-circle placed directly to the side of the quadrat, size measurements will be made for the nearest limpets. Double sampling will be used to calibrate the enumeration method for counting larger epifauna in quadrats to the method of removing all organisms from within the quadrat and counting organisms in the laboratory.

At coarse textured and estuarine habitats, in addition to counting epifauna, infauna will be collected and preserved. Sorting will be limited to those taxa which are dominant and/or showed impact during the CHIA study (i.e. oligochaeta, amphipoda, and polychaeta). Counts and wet weight will be determined for each taxon.

Larger invertebrates such as sea stars, whelks, and anemones, which are important predator members of the intertidal community but are mobile and unevenly distributed, will be surveyed using 2-m wide strip transects from MHW to the water line. Additional surveys will be done by divers during high tides in order to get a better count of cryptic organisms that tend to seek refuge when emerged during low tides.

Coverage and extent of mussel beds or zones on oiled and reference sites will be estimated using a line intercept method. A series of transects perpendicular to the water mark will be traversed from MHW to the water line. The length of the intersection with mussel beds or dense mussel zones, as well as measurements of the size of each mussel zone or bed will be made. Subsamples from within each mussel zone or bed will be collected for size-frequency analyses.

3. Intertidal Fish Methods

Fish sampling methods will be similar to those employed during the CHIA studies. A one meter wide strip transect beginning at 1 MVD and orientated perpendicular to the MHW line will be sampled for intertidal fish. Percent cover by algae and substrate types will be measured using a point contact method. Fish species collected within the strip transect will be preserved, measured, and weighed. Abundance and biomass of fish per unit area will be computed from fish captured within each MVD. Resource selection techniques will be used to determine what habitats are preferred by intertidal fish.

In coordination with the line intercept invertebrate collections, percent cover of mussels, algal morphotypes, and substrate types will be estimated using a point contact method in a 1-m by 1-m quadrat frame. These data will aid in characterizing each site by substrate, algae, and invertebrates, and allow determinations of habitat preference by intertidal fish.

Experimental Design Verification

One way of assessing our ability to select matched pairs of oiled and reference sites would be to use existing reference sites, select a new set of reference sites that matched the old reference sites (using criteria that are the same as those used in previous oiled-reference comparisons), sample at the old and new matched reference sites, and determine if there are significant differences among these. This process ignores possible biases related to oiling. It may be, for example, that wind and currents that bring oil to a site make the universe of potential oiled sites different from the universe of potential reference sites.

A second approach is to rely on an oil spill simulation model to define a potential universe of "simulated oiled" sites, select a set of "simulated oiled" sites from this universe, select matched reference sites, sample at "simulated oiled" and matched reference sites, and test for significant differences among sites. This approach also has potential drawbacks. Existing simulation models are very coarse grained and outputs from these models would likely result in large sections of coastline being simulated as oiled. This is in contrast to actual oiling observations which indicated that very often, heavily oiled and unoiled beaches were in close proximity to one another. Because of the coarse grained nature of the simulation models, "simulated oiled"

and reference sites may be separated by large distances. As a result, using "simulated" oiled and reference comparisons could result in a very conservative test of our ability to select matched pairs.

As a result of the imperfect nature of both designs, we propose to use a combination of approaches. First we will use an oil spill simulation mode to predict what portions of the Sound will be oiled in a simulated spill. We will overlay the shoreline types onto the simulated oiling map using existing GIS (Geographic Information System) databases, and select "simulated oiled" sites. Matched reference sites will be selected using the same criteria used to select reference sites after the spill. In addition, a second set of reference sites will be matched to those reference sites so that we can make reference-reference comparisons. The distance between these reference pairs will be no closer than the minimum distance between oiled and reference sites in the original injury assessment studies.

These studies will be conducted only within Prince William Sound and only within two selected habitat types (sheltered rocky and coarse textured beaches). Sites from both habitats will be selected in 1995, but only the sheltered rocky habitat will be sampled in that year. Coarse textured beaches will be sampled two years later in 1997. A total of 5 "triplets" of sites (a simulated oiled site, its matched control, and a second control matched to the first) will be sampled in both sheltered rocky habitat and coarse textured beaches. The community attributes that will be measured and the sampling methods will be similar to that described for the monitoring program.

C. Schedule

Oct-Dec 94 GIS selection of additional sites for experimental design verification
Jan-Apr 95 Obtain helicopter charter/boat charters and visit sites selected by GIS
May-Jun 95 Sample on CHIA sites in PWS
Jun-Jul 95 Sample on additional sheltered rocky sites in PWS
Jul-Sep 95 Sample analyses in laboratory
Sep-Dec 95 Data analysis/report writing
Apr 96 Submit annual report for FY 95

The site selection for the verification for the intertidal reference sites will be conducted during early May 1995. We plan to select reference sites for both the sheltered rocky and coarse textured sites at this time. The sampling of these reference sites will be conducted for the sheltered rocky habitats in late June 1995 and for the coarse textured habitats in June 1997. The results of the site selection for the sheltered rocky habitats will have to be available to the team doing the intertidal monitoring by early June 1995.

May-Jun 96 Sample on CHIA sites in CIK and KAP
Jun-Sep 96 Sample analyses in laboratory
Sep-Dec 96 Data analysis/report writing
Apr 97 Submit annual report for FY 96
May-Jun 97 Resample CHIA sites in PWS
Jun-Jul 97 Sample on additional coarse textured sites in PWS
Jul-Sep 97 Sample analyses in laboratory
Sep-Dec 97 Data analysis/report writing
Apr 98 Submit annual report for FY 97
May-Jun 98 Resample CHIA sites in CIK and KAP
Jul-Sep 98 Sample analyses in laboratory
Sep-Dec 98 Data analysis
Jan-Jun 99 Report writing
July 99 Submit final report for project

D. Technical Support

Principal investigators from the University of Alaska School of Fisheries and Ocean Sciences, will cooperate to provide expertise on different aspects of the intertidal study: algal, invertebrate and fish taxonomy and ecology. All mobilization and demobilization efforts associated with the charter vessel will be accomplished through the Seward Marine Center in Seward, Alaska. A project manager will oversee project logistics and personnel.

All sample and data analysis will take place at the School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, the Juneau Center for Fisheries and Ocean Sciences and at Coastal Resources Associates, using available computers and established data management services. A contract will be issued for the use of research vessels able to support the field work in Prince William Sound. A similar contract will be established for air taxi support between Anchorage and Prince William Sound.

A contract will be issued to Coastal Resources Associates (CRA) of Vista, California and to Western EcoSystems Technology, Inc. (WEST) for the experimental design verification aspect and to assist with the monitoring program. CRA and WEST have been involved with the CHIA study since 1989, and have played an integral part in the experimental design and data analysis procedures. In order to maintain consistency with the data collection, experiment modifications, analyses and report writing, it will be necessary to continue the existing contracts established with CRA and WEST.

The GIS databases developed by the Department of Natural Resources will be an integral part of this program. We will require their assistance in integrating the NOAA oil spill model into the GIS database and in developing the GIS model to select the reference sites.

E. Location

FY 95 and FY 97: This study will take place in the intertidal zone on Prince William Sound sheltered rocky, exposed rocky, coarse textured, and estuarine sites.

FY 96 and FY 98: This study will take place in the intertidal zone on Cook Inlet-Kenai Peninsula sheltered rocky, coarse textured and estuarine sites and on Kodiak-Alaska Peninsula sheltered rocky and coarse textured sites.

PROJECT IMPLEMENTATION

The original CHIA project was implemented by the Alaska Department of Fish and Game (Phase I) and the U.S. Forest Service with a contract to the University of Alaska (Phase II). At this time the project should be implemented by the University of Alaska through the Habitat and Restoration Division of the Alaska Department of Fish and Game. The University has the historical records of the sites and all of the raw and processed data from 1989 to 1991. The University is in the best position to assure the consistency of the data to allow for comparisons to the previously collected data. The Alaska Department of Fish and Game is also currently involved in the monitoring and restoration of the nearshore through existing contracts with the University for work in the subtidal (S. Jewett) and at Herring Bay (R. Highsmith and M. Stekoll).

In addition, both CRA and WEST were key players in the original site selection and ACIP experimental design. Verification of the experimental design will be difficult to perform without input from these two entities and the University of Alaska.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This multi-disciplinary study will be conducted by a team of scientists with first hand experience in the monitoring of the effects of oil in Prince William Sound. This team of the investigators has been working together over the past five years in evaluating the effects of the *Exxon Valdez* oil spill on intertidal and subtidal communities. Principal investigators from the University of Alaska Fairbanks and University of Alaska Southeast will be coordinating efforts to study interactions between key algae, invertebrate and fish. Coastal Resources Associates, Inc. will be consulted for the selection process for the additional sites needed for verification of the matched pair design. Western EcoSystems Technology, Inc., will be consulted for the site selection procedures, for sampling protocols that will enable comparisons from the destructive sampling efforts used in 1989-1991 to the non-destructive sampling efforts to be used for this study, and for statistical analyses of all data.

FY 95 BUDGET (\$K)

Personnel	9.0
Travel	0.0
Contractual	852.7
Commodities	0.0
Equipment	0.0
Subtotal	861.7
Gen. Admin.	30.9
Total	892.6

Herring Bay Monitoring and Restoration Studies

Project Number:	95086C
Restoration Category:	Research (continued)
Proposed By:	University of Alaska
Lead Trustee Agency:	ADFG
Cost FY 95:	\$904,200 (includes \$327,300 for data analysis and report writing on FY 94 work)
Cost FY 96:	\$789,800
Total Cost:	Unknown
Duration:	6 years
Geographic Area:	Herring Bay, Knight Island, Prince William Sound
Injured Resource/Service:	Intertidal organisms

INTRODUCTION

Following the *Exxon Valdez* oil spill (EVOS) and subsequent clean-up activities, research was conducted under the Coastal Habitat Injury Assessment (CHIA) program within the shallow subtidal and intertidal zones in the oil-affected habitats in Prince William Sound (PWS), and in the intertidal zones in Cook Inlet - Kenai Peninsula (CIK), and Kodiak - Alaska Peninsula (KAP). In addition, the Herring Bay Experimental and Monitoring Studies were conducted within Herring Bay, Knight Island, in Prince William Sound. All of these projects found damage to both the shallow subtidal and intertidal invertebrate and algal communities. Significant differences were detected between oiled and reference sites for grazing invertebrates such as *Tectura persona*, *Lottia pelta*, *Littorina sitkana*, and *L. scutulata* and for the primary space competitors *Fucus*, *Mytilus*, and several species of barnacles. Most of the invertebrates showing damage are prey for either other invertebrates or for foraging birds or marine mammals. Further research will allow better interpretations of key relationships in the damaged nearshore ecosystem.

Several ongoing monitoring and experimental studies have continued in Herring Bay since 1990 and are continuing through the 1994 field season. In addition to these studies, several new experiments are proposed to identify important community interactions between and among invertebrates and algae for determining factors that limit or control recovery. More specifically, the proposed studies are designed to answer one or more of the following ecosystem process questions:

1. Do dominant competitors and resident predators limit recovery of the damaged intertidal community? Included within this question are whether the presence of certain grazers limits the recovery of algal species.
2. Are predators limited by reduced populations of prey species? Included in this question are the affects of reduced algal cover as a food source to grazers.
3. Is the recovery of the community structure limited by recruitment processes?
4. Do physical processes limit recovery of damaged intertidal species, including the effects of damaged species that act as structure and protection for other species?

A combination of new and continued experiments in Herring Bay is proposed to elucidate the ecosystem processes that control community structure and recovery.

NEED FOR THE PROJECT

Five years after the EVOS, several intertidal species are still showing damage, including *Fucus*, the important structural component of the intertidal ecosystem. Continued monitoring of several key invertebrate and algal species in Herring Bay will allow estimates of the degree and rates of recovery of damaged species. This project will aid in defining the rates and potentials for recovery of damaged intertidal resources by ascertaining the major limitations to settlement, recruitment, and growth of *Fucus* and of invertebrates such as barnacles, mussels, and limpets.

A restoration aspect of the experimental study is focusing on the restoration of the damaged *Fucus* populations in the upper intertidal. This experiment is testing the feasibility of using a biodegradable substrate seeded with *Fucus* embryos to recolonize the high intertidal habitat by reducing heat and desiccation stress.

PROJECT DESIGN

A. Objectives

The objectives of this study are to identify the key relationships between damaged intertidal invertebrates and algae, to monitor the rates and degree of recovery of damaged intertidal resources, and to measure the natural rates and the feasibility of *Fucus* restoration in the upper intertidal.

These objectives will be accomplished by focusing each experiment to answer one or more of the following questions:

1. Are some species limited by predation and/or competition?
2. What limits food availability for grazers (i.e. limpets, littorines) and predators (i.e. *Nucella*)?
3. Is recovery limited by recruitment and, if so, what are the limiting factors?
4. How do physical factors, such as reduced protective cover or water circulation, limit species recovery?

We have keyed each experiment listed below to these question numbers.

B. Methods

Monitoring (Ongoing)

Population dynamics (1).

Population dynamics of *Fucus*, sessile invertebrates, and grazers will continue to be quantified in established quadrats at six pairs of oiled and reference sheltered rocky and coarse textured sites. Organisms will be counted within six quadrats that have been permanently established within each of the first three meters of vertical drop (MVD) below mean high water. The quadrats will be visited twice during the summer. The number of *Fucus* plants in various size classes will be determined. Reproductive status and condition of the plants will also be recorded. Limpets, *Nucella spp.*, and *Littorina sitkana* will be counted, and subsamples of each will be measured.

Fucus egg settlement (3)

Fucus egg settlement on oiled and control sites will continue to be monitored because of its importance to *Fucus* recovery. Grooved plates designed to catch *Fucus* eggs will be placed at three tidal levels (0.5, 1.0, and 2.0 MVDs) along four transects at each of four pairs of sites. The number of eggs settled on plates after 24 hours will be recorded. The experiment will be repeated three consecutive days at each site.

Experimental (Ongoing)

Fucus/limpets/other algae interactions (1,3,4)

Evidence indicates that ephemeral algae colonized better in areas devoid of *Fucus*, while in areas where the *Fucus* beds remained relatively intact, ephemeral algae were less abundant. *Fucus* may release allelochemicals which assist in both interplant competition for space and resources and grazer deterrence. To investigate this we will continue to monitor cleared plots with various sized buffer zones that were established in 1993. Each replicate consists of four plots at 2 MVD, one for each buffer zone treatment plus an unmanipulated control. Circular

buffer zones of 50 cm, 1 m, and 2 m radii were cleared around monitored plots. The sampling area consists of a cleared 25 cm radius circle. Percent cover, understory cover, and primary space occupancy will be measured. In addition, the effects of reduced *Fucus* cover on limpet densities will be determined. Limpet densities will be followed over time and comparisons made between plots of differing size and between treatment plots and controls.

Nucella/mussel interactions (1,2)

The size-frequency distributions of mussels will continue to be studied within the mussel band on three matched pairs of sites. Two major predators on mussels are the whelks *Nucella lima* and *N. lamellosa*. Both of these species will be censused on each site in an attempt to relate *Nucella* densities to the size-frequency distribution and densities of mussels on each site.

Nucella exclusion and inclusion cages will be maintained over randomly selected plots within the mussel zone on each of the sites to estimate their rates of predation on mussels and their influence on the size-frequency distributions of mussel populations.

Barnacle species interactions (1,3)

Data collected during the Coastal Habitat Intertidal Assessment project showed significantly higher densities of *Chthamalus dalli* on oiled sites compared to control sites within the first three MVDs. In undisturbed systems, *Chthamalus* species tend to be restricted to the highest zones in the intertidal, as they are excluded by the superior space competitors, *Balanus glandula* and *Semibalanus balanoides*, in the lower intertidal. *Chthamalus dalli* appears to be the barnacle species that initially benefited from the free space created by the oil spill and clean-up activities. We will continue to monitor recruitment and post-settlement survival ratios of *C. dalli* compared to *S. balanoides* and *B. glandula*. The three sites used in this study are all on oiled vertical rock faces.

Effects of herbivores on *Fucus* recruitment, growth, and survival (1,3)

The effects of herbivores on *Fucus* recruitment, survival, and growth will be investigated.

Heterogeneous polycarbonate plates manipulated by three treatments of full cage, open cage, and no cage will be set out at three tidal levels (1, 2, and 3 MVDs). The number of germlings and size of the five largest germlings on each plate will be recorded. The experimental design will be repeated at six sites.

Mussel recruitment/filamentous algae interactions (3,4)

Mussel larvae tend to settle temporarily on filamentous algae in the mid and low-intertidal zones. On sites used for *Nucella*/mussel interaction studies, filamentous algal percent cover will be determined within each MVD. Filamentous algae samples will also be collected at each MVD three times per field season to determine the number of young mussels that have settled onto the algae. The data will be related to the size-frequency distribution data collected in the *Nucella*/mussel interaction study.

Substrate use by *Fucus* (3,4)

Substrates used by large and small *Fucus* will be examined in relation to substrate availability. The proportion of plants from three different size classes (<2 cm, 2-10 cm, and >10 cm) using cracks, barnacles, rock surface, and other substrates will be compared to relative availability of the different substrates.

Effects of physical environment on *Fucus* recruitment (3,4)

The effects of physical environment on *Fucus* recruitment will continue to be studied. *Fucus* recruitment will be monitored on tiles with various sized grooves placed under a variety of conditions including in and out of *Fucus* canopy, at different tidal levels, and at oiled and control sites.

Effects of water movement on mussel and *Fucus* growth rates (4)

To test whether mussel growth rates on oiled sites within Herring Bay are different from those on control sites, tagged and measured mussels have been caged in the intertidal and periodic measurements will be made to determine growth rates. Any differences detected may be due to differences in relative water motion on oiled versus control sites. To test this idea, calcium sulphate dissolution rates will be determined on all sites where mussel growth rates are being measured.

Study of water movement effects on *Fucus* growth with and without *Fucus* canopy will continue. Two similar plants will be marked at 18 sites varying in exposure to waves. All plants able to touch one of the marked plants will be removed, and the canopy around the other marked plant will be left intact. Average water velocity will be measured at each site by deploying calcium sulfate dissolution sticks.

Experimental (New)

Fucus/barnacle/mussel interactions (1)

This study is designed to elucidate the positive or negative interactions among *Fucus*, mussel, and barnacle populations. Treatments will include replicated reciprocal removal of *Fucus* and barnacles in a mixed *Fucus*/barnacle zone; reciprocal removal of *Fucus* and mussels in a mixed *Fucus*/mussel zone; reciprocal removal of each species in a mixed *Fucus*/mussel/barnacle zone; and control treatments where no removal occurs. Recruitment and existing densities of each species will be monitored over time.

Oystercatcher/limpet/mussel interactions (1)

Because of the importance of integrating study of the intertidal system with that of external interacting systems, the effects of oystercatcher predation on intertidal community structure will be investigated. Oystercatchers will be excluded from foraging areas of the intertidal using cage domes. Plots within and outside of exclosures will be monitored for changes in intertidal community structure.

Effects of epiphytes on *Fucus* reproduction (1)

The effects of epiphytes on *Fucus* reproduction will be examined. Using existing population dynamics data, comparisons between percent cover of different types of epiphytes and both the number of reproductive plants and the mean number of receptacles per reproductive plant will be made.

***Fucus* as habitat for invertebrates (2,4)**

The importance of *Fucus* as a structural habitat for intertidal invertebrates will be investigated. Similar plants located at 3 MVDs will be randomly chosen to be clipped and bagged while submerged under high tide or while exposed during low tide. Invertebrates trapped by the bags will be enumerated by taxa.

Effects of mobile predators (1,2)

Seastars are unevenly distributed in Herring Bay on coarse textured and sheltered rocky shorelines. We will census the numbers of these mobile predators on the five matched pairs of population dynamics sites and on the mussel study sites. These predator densities will be related to potential prey densities on the same sites.

Nucella are intense predators in the mussel zone and their densities will be determined in the mussel zone on selected sites as described under *Nucella*/Mussel Interactions. Many *Nucella* have been removed from the intertidal as prey for birds. Avian exclusion/*Nucella* inclusion cages will be placed in the intertidal on selected sites next to *Nucella* inclusion cages that allow access to bird predators. Comparisons between these two treatments will be made for determinations of avian predation pressure on *Nucella* populations around Herring Bay.

Effects of ice scouring (4)

Several areas within Herring Bay, especially on the eastern side of the bay, where most of the control sites are located, have shown severe destruction between a September field visit and a visit the following May. The loss of *Fucus*, mussels, and barnacles occurs in wide bands along the shoreline. The evidence (crushed mussel shells and barnacle tests and *Fucus* holdfasts ripped out) indicate that this destruction may have resulted from ice scouring over the winter. The extent of ice scouring within the intertidal will be addressed by placing painted and/or pencil rebar covered cement blocks in the intertidal in locations where ice scouring is suspected to have decimated populations in the past and in areas where no ice scouring has been observed. The condition of the paint and rebar will be assessed the following spring (1996).

Effects of desiccation on *Fucus* egg release (4)

Observations suggest that desiccation/temperature might have a negative impact on *Fucus* egg release. These effects will be tested by comparing the number of eggs released by plants under direct sunlight compared to artificially shaded plants. Twenty *Fucus* plants will be placed on a hard surface in the sun with ten randomly chosen to receive shading and watering. Desiccation rates and temperature will be recorded near each plant. After one, two, and three days of exposure, randomly chosen receptacles from each plant will be rehydrated for 24 hours and the number of released eggs will be assessed.

Structural importance of *Fucus* (4)

Observations suggest that the physical structure that *Fucus* provides to the intertidal environment might be more important than other resource attributes. To test this idea, artificial *Fucus* plants will be mounted above polycarbonate plates with heterogeneities. Differences in recruitment, growth, and survival of intertidal invertebrates on the plates and the plants with artificial *Fucus* canopy, no canopy, and *Fucus* canopy will be assessed.

Restoration (Ongoing)**High intertidal *Fucus* restoration (3,4)**

Restoration of severely damaged intertidal algal populations has been started on a small scale basis at a heavily oiled rocky intertidal site in Herring Bay, Prince William Sound. A series of high intertidal plots were started in 1992 to test various techniques for increasing *Fucus* recruitment. These techniques included the attachment of erosion control fabrics to the rock substrate to produce a more favorable microclimate for small *Fucus* plants. Surveys made in May 1994 showed that there were dense populations of small *Fucus* plants on the coconut fiber fabric deployed in 1993, especially in the lower portions and where we had transplanted fertile plants. We will continue to monitor these plants to quantify their reproduction and their contribution to new recruitment on the substrate around the fabric strips. We will also test other methods for seeding the fabric with embryos to get higher densities of plants.

We have identified other areas of Prince William Sound where *Fucus* may not be recovering by using the Oil Spill Geographical Information System (GIS) databases assembled by the Alaska Department of Natural Resources (DNR). We have conservatively estimated that there are 12 miles of coastline throughout Prince William Sound that fit the physical criteria of the unrecovered beaches we have seen in Herring Bay. The results of surveys of some of these sites in May 1994 showed that the upper limit of *Fucus* at the oiled sites is approximately a half meter lower than populations at control sites. We will continue to survey a random selection of beach segments identified by the DNR GIS as being in the potentially unrecovered category. Surveys will quantify *Fucus* density in the 1 and 2 MVD tidal levels, as well as the upper limits of the *Fucus* on the transects.

C. Schedule

(Information not provided.)

D. Technical Support

Principal investigators from the University of Alaska School of Fisheries and Ocean Sciences, will cooperate to provide expertise on different aspects of the intertidal study: invertebrate and algal taxonomy and ecology. All mobilization/demobilization efforts associated with the charter vessel will be accomplished through the Seward Marine Center in Seward, Alaska. A project manager will oversee all logistical and personnel aspects of the project.

All sample and data analysis will take place at the School of Fisheries and Ocean Sciences, University of Alaska Fairbanks and the Juneau Center for Fisheries and Ocean Sciences, using available computers and established data management services.

A contract will be issued for the use of a research vessel able to support the field work in Herring Bay. This vessel must be able to meet all University safety requirements and be of sufficient size and configuration to meet the needs of the science specified above. Bid specifications will be drawn up and request for proposals will be sent out to prospective bidders. A similar contract will be established for air taxi support between Anchorage and Herring Bay. A contract will also be issued to Coastal Resources Associates (CRA) of Vista, California. CRA has been involved with the Herring Bay study from its inception in 1990. In order to maintain consistency with the data collection, experiment modifications, analyses and report writing, it will be necessary to continue the existing contract established with CRA.

We will need updates of the GIS model from the Alaska Department of Natural Resources to include various parameters for shoreline aspect and possibly oiling classification.

E. Location

The proposed restoration, monitoring, and experimental studies will be conducted in the Herring Bay, Knight Island area. Intertidal studies were initiated in Herring Bay in May 1990 and are continuing through the 1994 field season. Herring Bay was heavily oiled in 1989, and was a central area for clean-up efforts. The bay was chosen for experimental studies because of its oiling history and close proximity to non-oiled sites used as controls.

PROJECT IMPLEMENTATION

The Alaska Department of Fish and Game has implemented the Herring Bay Experimental and Monitoring Study for the last two years. Due to the successful coordination of the University of Alaska with this agency, a continuation of this partnership should continue for future funding.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Principal investigators from the University of Alaska Fairbanks and University of Alaska, Southeast will be coordinating efforts to study interactions between key invertebrate and algal species. In addition, Dr. Stekoll will be cooperating with Dr. Deysher from Coastal Resources Associates for field sampling for the Restoration of High Intertidal *Fucus* study. Dr. Brad Andres of the U.S. Fish and Wildlife Service will be cooperating with the oystercatcher experiments.

The studies at Herring Bay are closely integrated with the Shallow Subtidal Studies and the Coastal Habitat Monitoring Studies. In addition this study will provide valuable information for use by studies of higher trophic level organisms such as those on shore birds, ducks and otters, that utilize the intertidal and shallow subtidal ecosystems.

FY95 BUDGET (\$K)

Personnel	9.0
Travel	0.0
Contractual	864.0
Commodities	0.0
Equipment	0.0
Subtotal	873.0
Gen. Admin.	31.2
Total	904.2

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Relation of Sea Urchin Population Structure to Recovery of Injured Nearshore Vertebrate Predators

Project Number:	95087
Restoration Category:	Research (new)
Proposed By:	University of Alaska Fairbanks and Coastal Resources Associates, Inc.
Lead Trustee Agency:	ADFG
Cost FY 95:	\$48,800
Cost FY 96:	\$78,300
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sea otter, intertidal organisms

INTRODUCTION

Sea urchins, a favored food of otters, consume large amounts of algae (especially kelps) and can have profound effects on the structure of nearshore ecosystems. Prior to the spill there were few urchins in Prince William Sound, presumably because of predation by otters. It was predicted that a decrease in otter populations, as a result of the *Exxon Valdez* oil spill, may lead to increases in urchin densities and subsequent decreases in kelps. Observations in 1990, 1991 and 1993 suggest that, in fact, urchin populations are increasing within the Sound. We noted higher than usual urchin densities in 1993 under cobbles in the lower intertidal, and occasional large patches of small urchins in subtidal eelgrass beds. Monitoring of epibenthic invertebrates within the Sound has been carried out previously (Subtidal Studies, University of Alaska), but there have been no previous efforts to specifically examine sea urchin populations.

This project will examine changes in the distribution and abundance of sea urchins in Prince William Sound, and will examine the availability of sea urchins as food for injured sea otter resources. Questions that will be addressed regarding sea urchin populations are:

1. Are urchin population densities increasing in the Sound?
2. If so, is this increase related to the a lack of predation by otters?
3. Is the increasing urchin population a potential food source for recovering otter populations?

NEED FOR THE PROJECT

One hypothesis for a lack of recovery of sea otters is that food availability is limiting. Sea urchins provide an important potential food source for otters. An increase in urchin populations may provide food for otters that may offset otherwise impoverished food supplies.

In addition, increases in sea urchin densities may lead to drastic changes within the benthic community. Sea urchins can have profound effects on nearshore communities, including a reduction in kelps which provide substrate for herring spawn. We need to monitor these potential changes.

PROJECT DESIGN

A. Objective

Document changes in the population density of sea urchins and their availability as food for sea otters.

B. Methods

Examine sea urchins at shallow (< 20 m) subtidal sites where sea otter densities currently range from absent to high. Population density, size structure, recruitment, and growth of urchins will be determined at all sites. Define urchin habitat. Then select sites (at random) from the universe of sites within each category that has appropriate urchin habitat. At each site, determine the size frequency and density of urchins. Examine growth of urchins at representative sites by marking urchins with a calcein dye, releasing them, and collecting urchins at a later time and examining growth rings.

C. Schedule

The field work for this project will begin in June 1995 and be completed in September 1995. Laboratory analysis of urchin growth will be completed February 1996. Data analysis and draft report preparation will be completed in May 1996. Deliverables will consist of a FY 95 progress report to be submitted in September 1995, and a final report to be completed by May 1996. Field work and reporting will follow a similar schedule for subsequent years.

D. Technical Support

Outside technical support will be required for the analysis of growth ring data.

E. Location

The project will be undertaken in western Prince William Sound.

PROJECT IMPLEMENTATION

The principal investigators have been conducting damage assessment/monitoring studies in the shallow subtidal regions of Prince William Sound since 1989. Since these studies have mainly been implemented through Alaska Department of Fish & Game (ADFG), and since this project will overlap with the ongoing work in the subtidal eelgrass habitat, it is appropriate for this project to also be implemented through ADFG.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This study is a component of the nearshore ecosystem project. Information on the food and feeding habits of sea otters will be critical in evaluating the interactions between otters and urchins.

FY 95 BUDGET (\$K)

Personnel	6.0
Travel	0.0
Contractual	39.2
Commodities	0.0
Equipment	0.0
Subtotal	45.2
Gen. Admin.	3.6
Total	48.8

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Information Management System

Project Number:	95089
Restoration Category:	Administration, Public Information and Science Management
Proposed By:	Molly McCammon, Director of Operations <i>Exxon Valdez</i> Oil Spill Trustee Council
Lead Trustee Agency:	All
Cost FY 95:	\$590,700
Cost FY 96:	\$590,700
Total Cost:	Unknown
Duration:	Ongoing
Geographic Area:	Oil spill area
Injured Resource/Service:	Multiple resources and services

INTRODUCTION

This project proposes to further develop an information management system that began with establishment of the Oil Spill Public Information Center (OSPIC) in September 1990 as a public repository for information and materials generated as a result of cleanup, damage assessment and restoration efforts following the *Exxon Valdez* oil spill. When fully developed, this system will contain distinct but interrelated components designed to make information that is relevant to the *Exxon Valdez* oil spill readily available for use by managers, scientists, and the public. This information will support restoration planning, management and policy making, scientific research and coordination, and public information. A central access point will be the OSPIC, with the potential for the establishment of additional access points as needs or interests are identified. In addition, this project would plan and implement an update and distribution program for EVOS information in digital format for use by the general public and cooperating agencies, managers and scientists.

NEED FOR THE PROJECT

An Information Management System supports the Mission of the Trustee Council in its efforts to restore the injured environment. Through the management, synthesis and dissemination of information and materials collected as a result of the *Exxon Valdez* oil spill, meaningful public

participation in the restoration process, as mandated by the settlement agreement between the state and federal governments and Exxon, is facilitated.

the OSPIC responds to inquiries from local, state, national, and international users, including but not limited to students (from preschool to graduate school), educators, scientists, government agency personnel, state and federal legislators, environmentalists, the business community, the media, the legal profession, and other libraries and information providers.

In addition, the OSPIC staff provides priority information service to the Trustee Council, the Executive Director, the Director of Operations, the Public Information Officer, and the staff-of the *Exxon Valdez* Restoration Office (EVRO). Through the reference services provided to restoration project personnel, the OSPIC serves all restoration activities.

Although the OSPIC does an excellent job at distributing what information is available, it is still unclear what information has been collected, what additional information exists or would be useful, how to acquire it, who maintains it, and how to access it. This project provides an opportunity for the Trustee Council to efficiently synthesize and disseminate this pool of information, thereby providing a lasting legacy of oil spill related work.

PROJECT DESIGN

A. Objectives

The objectives of the Information Management System are:

1. Compile, manage, synthesize, and disseminate currently available information about the *Exxon Valdez* oil spill and the Trustee Council (including damage assessment and restoration final reports) in a manner which can easily and effectively be utilized and understood.
2. Provide public access to local, state, national, and international users of this information through the Oil Spill Public Information Center.
3. Maintain the Trustee Council Administrative Record, a growing collection of over 2,000 documents produced for and by the Trustee Council, to allow public access and to document the decision making process of the Trustees.
4. Develop two distinct but interrelated products as described below, for initial use and distribution as part of an overall strategy to provide up-to-date information on the status of restoration and recovery as well as historical knowledge of the *Exxon Valdez* oil spill.

- a. EVOS Information Summary. An interactive multimedia computer program will be developed to allow the user to explore *Exxon Valdez* oil spill information. This information will be organized to present a variety of topics in a logical, hierarchical structure. Information will be presented graphically with links to more detailed in-depth textual information. Emphasis will be given to general information about the oil spill, including but not limited to the natural history of the spill area and oil spill history, including response, oil spill sponsored research, and the status of ongoing restoration efforts. The end point for most users would be a citation for further reference or actual study results, the references' physical location, and availability in the form of an electronic bibliography.

This type of program will employ an easy to use mouse-driven graphical user interface and will be ideal for educational settings such as schools, nature centers, visitor centers and home or library use for the general public. The product development approach will provide a great deal of flexibility and provide for expansion as new information becomes available, thus providing a current status report on restoration and recovery to date.

- b. Geographical Database Application. A wide variety of complex geographic data sets have been compiled and used by the many organizations involved with the response, damage assessment, and restoration stages of the *Exxon Valdez* oil spill. The electronic information is sophisticated in its structure and detailed in its history, making it difficult to access by non-technical staff. Conventional access has been through the maps and other reports disseminated by the technical services group and the OSPIC library. A systematic compilation of the data resources, combined with a "point and click" software interface, will permit a broader application of the geographic information which serves as a common base to a wide range of ecosystem management strategies. The existing strengths of institutional ties among the data producers will continue to serve as the backbone of this project, which is coordinated through the present repository site at the Alaska Department of Natural Resources, Land Records Information Section (LRIS).

Of great importance to the success of an up-to-date information system is support for database maintenance and annual updates. It should be noted that the goal of this project involves the dissemination of publishable information (analyzed data) only. It should not be confused with the dissemination and distribution of raw or unverified scientific data.

B. Methods

Integration

The Director of Operations will oversee the integration of Trustee Council-funded research in order to ensure cost-effectiveness and to maximize the ability to synthesize information and data collected from these efforts.

Reference Service

All OSPIC staff members respond to information requests made by visitors to the library, or by telephone, fax, mail, or electronic mail from around the world. During the past four years, the OSPIC staff have received over 6,500 visitors including visitors from 25 countries, responded to 8,500 on-site and off-site requests for information, processed 1,300 interlibrary loans of materials to and from other libraries, performed 1,200 on-line database searches, and distributed over 16,000 documents. The OSPIC also serves *Exxon Valdez* Restoration Office personnel, including the Executive Director, the Director of Operations, the Restoration Work Force, the Public Information Officer, and other agency personnel.

Cataloging

Materials acquired by the OSPIC staff are analyzed and described for entry into the OSPIC collection according to standard library practice. Materials are then made ready for the shelves with appropriate physical processing. The OSPIC collection is cataloged in the online database of the Western Library Network (WLN), a growing consortium of about 540 libraries in the western part of the United States, Canada, Australia, Korea, and Japan. Librarians from any member library can search the WLN database to locate OSPIC materials.

Computer Network and Technology

To conduct research and catalog new items for the collection, the OSPIC staff uses a Novell-based local area computer network linked by modem to WLN, DIALOG, and other databases. WLN's LaserCat, a CD-ROM product, functions as the OSPIC public access catalog. In addition, the OSPIC staff uses the Internet, a global network of over 10,000 computer networks in 85 countries linking 20 million users, to communicate with library users, seek out reference sources, and disseminate information. The OSPIC staff also provides Internet training to personnel in the *Exxon Valdez* Restoration Office.

Publication of Final Reports

Working in conjunction with the Director of Operations, the OSPIC staff coordinates the collection, publication and distribution of the Natural Resource Damage Assessment Final Reports and the Restoration Project Final Reports to the National Technical Information Service (NTIS), other libraries, local commercial copy centers and the general public. The OSPIC Technical Services Librarian began the coordination of the cooperative cataloging of interim reports with a cataloger at the Alaska State Library and will continue with the final reports.

Trustee Council Support

The OSPIC is a repository for documents produced for and by the Trustee Council, including meeting transcripts, agendas, budgets, work plans, correspondence, and public comments. The Trustee Council Administrative Record is maintained as a certified Administrative Record to track the decision making process of the Trustees and to address issues of accountability. The OSPIC staff distributes Trustee Council publications, such as annual reports, work plans, and information packets. An electronic mailing list is maintained online whereby interested persons may receive email notification of Trustee Council activities and publications via the Internet. The feasibility of additional applications of the Internet is currently being explored.

Development of New Products

Seven fundamental steps will be applied in a coordinated manner to the development of both the EVOS Information Summary and the Geographical Database Application:

1. Establish an interagency/multidisciplinary group to assist in the establishment of product objectives, identification of user needs, and testing of product design.
2. Develop product design and prototype programs.
3. Solicit input from chief scientist, executive director, restoration staff, principal investigators, and OSPIC to ensure accuracy and completeness of information, utility of design, and program integrity.
4. Fully implement product design with continued meetings with the interagency/multidisciplinary group and cooperators to keep project focused and ensure accuracy.
5. Provide for demonstration and review of beta versions of final products to oil spill managers, scientists, and the public.
6. Develop documentation for both products, provide for review and publication.
7. Establish a mechanism to facilitate information exchange and provide for the periodic update and dissemination of both products.

C. Schedule**OSPIC**

Quarterly and annual reports documenting library usage, acquisitions, expenditures, and user information needs will be submitted by the designated deadline. The quarterly distribution of the "OSPIC News" will begin in September 1994.

New product development

Nov 94	Establish an interagency/multidisciplinary group
Jan 94	Develop program design and prototype program
Feb-July 95	Solicit technical and scientific input from OSPIC, Restoration Staff, and Principal Investigators in areas of expertise
Mar-July 95	Identify and develop information to be included in program templates. Refine product design and programming
Aug 95	Work with contractors, PIs, an interagency/multidisciplinary group, OSPIC, and restoration staff to QA/QC final product
Oct 95	Release of initial version of products
Nov 95	Peer Review
	With cooperation of an interagency/multidisciplinary group, OSPIC, Executive Director, Chief Scientist, and restoration staff, identify information gaps and areas to be targeted for annual update
Dec 95	Final release of products

D. Technical Support

The analyst programmer located in the Restoration Office provides maintenance of the LAN computer network and assistance in establishing a full-text online service for the public.

New product development will require support for digital scanning of slides and photographs. In addition, computer programming support and peer review will be needed in the initial product development stage and as a final review process to ensure that program development is technically correct and accurate oil spill information is presented.

E. Location

The project will be coordinated by the Director of Operations in the Anchorage EVOS Restoration Office, located at 645 G Street, Anchorage, Alaska, 99501, which is also the site of the Oil Spill Public Information Center. Users in the spill area and state, national and international users are served by mail, telephone, fax, and electronic mail.

PROJECT IMPLEMENTATION

The *Exxon Valdez* Restoration Office in Anchorage serves as the primary repository of information on the *Exxon Valdez* oil spill, related events and issues, and the actions of the EVOS Trustee Council in working towards restoration of the spill affected area. The OSPIC has been an integral part of the restoration process since it was established in 1990. A major restructuring by Executive Director Jim Ayers in early 1994 has maximized library efficiency and reduced operating costs. The OSPIC Director reports directly to the *Exxon Valdez* Oil Spill Trustee Council's Director of Operations.

Since the OSPIC collection is narrowly focused on a single, albeit complex event, the staff can provide more in-depth reference service than other libraries where *Exxon Valdez* oil spill related materials are only a small fraction of the entire collection. The OSPIC staff receives frequent referrals from local public, academic, and special libraries, as well as numerous school districts throughout the nation. In addition, they have developed extensive contacts with state and federal agencies, private sector organizations, universities, and all types of libraries. These contacts enhance the ability of the OSPIC staff to serve the information needs of anyone participating in the restoration process.

In order to maximize the utility of information generated through the restoration process to resource managers, researchers, and the public, it is essential that the new products described in the Objectives section be developed. The Department of Natural Resources Oil Spill Project Office will provide the central focus for their development. DNR, Land Records Information Section (LRIS) is the current repository of Oil Spill GIS data and as such will have an important role in data maintenance, interface implementation, and as the facilitator in coordinating the updating and dissemination of GIS information compiled as part of this project. OSPIC will provide a central location for access and distribution of all products.

The product development will be implemented in three phases:

Phase One focuses on the development and dissemination of the two programs described above.

Phase Two, to be proposed for funding in FY96, will focus on the integration of the two previously developed products, and cross platform compatibility. Both products will initially be designed with the objectives of Phase Two in mind.

Phase Three will focus on the establishment of an on-line connection for access to the two original programs.

COORDINATION OF INTEGRATED RESEARCH EFFORT

A further development of the Trustee Council's current Information Management System will go a long ways toward furthering the coordinated integration of the Trustees' research efforts. This project provides a unique opportunity for all Principal Investigators to effectively disseminate the information gathered through their work to the general public, restoration staff, and the scientific community. The products generated as a result of this project have the potential to tie all EVOS-related research and historical information together into a meaningful picture for the lay person, scientist, and manager alike. As new information products are developed, meetings will be held with other information managers, GIS managers, and representatives of various scientific disciplines to ensure that the initial design maintains data integrity, achieves a common goal, and addresses the identified needs of principal investigators and managers in order to ensure coordination with the integrated ecosystem based approach to restoration.

FY 95 BUDGET (\$K)

Personnel	300.6
Travel	6.4
Contractual	197.8
Commodities	24.5
Equipment	2.5
Subtotal	531.8
Gen. Admin.	58.9
Total	590.7

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Mussel Bed Restoration and Monitoring in Prince William Sound and Gulf of Alaska

Project Number:	95090
Restoration Category:	Monitoring (continuation of 94090)
Proposed By:	NOAA, ADEC, and DOI
Lead Trustee Agency:	NOAA
Cooperating Agencies:	ADEC, DOI
Cost FY 95:	\$438,800 (includes \$160,400 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$216,400
Total Cost:	Unknown; periodic monitoring until recovery
Duration:	Unknown; periodic monitoring until recovery
Geographic Area:	Prince William Sound, Kenai and Alaska Peninsulas
Injured Resource/Service:	Intertidal organisms, and higher level consumers including harlequin ducks, black oystercatchers, juvenile otters, salmon, and herring

INTRODUCTION

This project will monitor oil concentrations in mussel beds and sediments restored during 1994, monitor natural recovery levels of unrestored beds in Prince William Sound, Kenai, and the Gulf of Alaska, provide logistical and staff support for comprehensive sampling of mussels for pristane levels in Prince William Sound which index copepod populations, and will finish report-writing and analysis for the field work completed in 1994 (project 94090).

The persistence of *Exxon Valdez* crude oil underlying some dense mussel (*Mytilus trossulus*) beds in Prince William Sound (PWS) and the Kenai and Alaska Peninsulas began to cause concern in the spring of 1991 and was confirmed in annual surveys by NOAA's Auke Bay Laboratory (ABL) and the National Park Service (NPS).

In 1992, ABL documented 25 mussel beds in PWS with underlying sediment concentrations in excess of 10,000 $\mu\text{g/g}$ total petroleum hydrocarbons (TPH). The lack of a clear indication of a reduction in petroleum hydrocarbon (HC) levels between 1992 and 1993 in mussels and underlying sediments led the Trustee Council to fund NOAA and ADEC to restore selected mussel beds in 1994. Approximately 15 mussel beds were restored. This proposal is for evaluation of the restoration process and monitoring of control (natural recovery) sites in PWS and for sampling and monitoring of oiled mussel beds along the Kenai Peninsula.

Field surveys along the Kenai and Alaska Peninsulas and Kodiak Archipelago were conducted in 1992 and 1993 to establish the geographic extent and intensity of oiling of contaminated mussel beds by the Department of Interior's National Park Service (NPS). There was no sampling in 1994. The National Biological Survey (successor to this work under NPS) portion of this study will be to resample oiled mussel beds in the Gulf of Alaska.

In addition, ABL will handle the logistics of sampling mussels for pristane analyses. Levels of pristane in mussels are an index for copepod populations. Copepods are alternative prey for marine predators which also prey on juvenile salmon. Measuring copepod production is important for the Prince William Sound Ecosystem Study, but the collection logistics have been integrated into this study.

NEED FOR THE PROJECT

The presence of substantial levels of petroleum hydrocarbons persisting under dense mussel beds in PWS and the Gulf of Alaska provides a continuing, potential source for oil to enter the food chain, impacting higher consumers, especially harlequin ducks, oystercatchers, juvenile otters, and humans. There is a possible link between the presence of oiled mussels and the disruption of reproduction in harlequin ducks and increased mortality in oystercatcher chicks.

Restoration (cleaning) of selected mussel beds (approximately 15 mussel beds were restored in PWS in 1994) should reduce potential exposure to HCs in higher predators such as harlequin ducks, oyster catchers and juvenile otters. Sampling mussels and underlying replacement sediments, and comparing changes in size and density of mussels is necessary to evaluate the success of this restoration method. Periodic sampling for hydrocarbons in oiled mussel beds along the Kenai Peninsula is proposed to document their recovery progress. This information is needed for decisions relevant to cleaning mussel beds in the future in both Prince William Sound and the Kenai Peninsula. Additional potential oiled mussel beds brought to the attention of the Trustee Council by the public and other projects will also be examined.

Logistics for collecting mussels for pristane analyses is complex as periodic sampling over the spring and early summer needs to occur to measure changes over this period. Mussels from approximately 32 sites in PWS are being collected. Logistics for collecting mussels for this purpose have been combined with this project to reduce overall field costs. Pristane analyses will be used to index copepod production which is used to evaluate prey-switching hypotheses by the Prince William Sound Systems Investigations. It is important for their research concerning salmon and herring.

PROJECT DESIGN**A. Objectives**

1. To evaluate the physical and biological stability of the 1994 restored oiled mussels beds by measuring petroleum hydrocarbon concentrations in mussels and underlying replacement sediments, measuring the size of the beds and calculating density of mussels (NOAA, ADEC).
2. To monitor natural recovery in levels of petroleum hydrocarbons in mussels and underlying sediments in oiled mussel beds in PWS not restored (NOAA, ADEC).
3. To monitor recovery in levels of petroleum hydrocarbons in mussels and underlying sediments in oiled mussel beds along the Kenai and Alaska Peninsulas (NPS).
4. To provide logistic and staff support for comprehensive sampling of mussels for indexing pristane levels in PWS. This project is closely coordinated among several resource groups (NOAA).
5. To complete analysis and report writing for the 1994 field work.

B. Methods

Sampling mussels, underlying sediments, and replacement sediments will follow the methods used in previous years and consists primarily of triplicate pooled samples of mussels and underlying sediments for petroleum hydrocarbon analyses. Beds cleaned in 1994 as well as control (natural recovery) beds will be sampled in PWS. Similar experimental design is used for documented oiled mussels beds along the Kenai and Alaska Peninsulas.

To assess physical and biological stability of a restored bed, other measurements will be taken to compare with precleaned bed condition, i.e. bed size and density of mussels. Photos will also be taken for comparison purposes.

Sediment samples will be analyzed by ultraviolet fluorescence. Selected sediments and mussels then will be analyzed by gas chromatography/mass spectroscopy (GC/MS) for quantitative measurements of HC analytes. All mussels collected for pristane concentrations will be analyzed by GC/MS.

Freezing, chain-of-custody procedures and record keeping will follow Natural Resource Damage Assessment protocol. Data will be analyzed using standard statistical methods, mapped using ABL's computerized data mapping system, and entered into the *Exxon Valdez* Restoration Hydrocarbon Database.

C. Schedule

Jan-April 1995	Logistics planning; evaluation of 1994 data for sites to actually sample; initiation and implementation of contracting for aircraft charter; and other preliminary planning for 1995 field season.
April 1995	Draft Report Submitted for 1994 field work.
April 1995	First PWS 1995 field trip during low tide series for sampling mussels at some established sites for pristane analyses.
May 1995	Second PWS 1995 field trip during low tide series for sampling mussels at some established sites for pristane analyses. Site visits to 1994-restored mussel beds and to sample and evaluate restoration process. Sampling of mussels and underlying sediments will be done at several control (natural recovery) sites.
June 1995	Third PWS 1995 field trip during low tide series for sampling mussels at some established sites for pristane analyses. Site visits to 1994-restored mussel beds and to sample and evaluate restoration process. Sampling of mussels and underlying sediments will be done at several control (natural recovery) sites. During low tide series, site visits and sampling of mussels and underlying sediments will be conducted in the Gulf of Alaska.
June-Oct 1995	Ongoing chemical and data analyses.
Oct 95-April 96	Ongoing chemical and data analyses.
April 1996	1996 Annual Report

D. Technical Support

With the exception of transportation contracts, NOAA's Auke Bay Laboratory, the National Biological Survey and AK Department of Environmental Conservation will provide all technical support.

E. Location

Prince William Sound, Kenai and Alaska Peninsulas.

PROJECT IMPLEMENTATION

Management of this study is proposed to be led by NOAA's ABL with one objective the responsibility of the NBS. ADEC will participate in the evaluation of restored mussel beds and sampling for natural recovery in unrestored oiled mussel beds.

All three agencies have accomplished previous research and restoration work related to this project, 1991-1994 (1994 Study #94090) and have site experience, access to site and HC data, and NOAA's ABL is the only laboratory currently conducting HC analytical analyses for Trustee environment samples.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Logistics and staff time will be shared and closely coordinated with field expertise needs and other activities under other projects particularly the proposed work on population structure of blue mussels in PWS. Data from this project will continue to be shared with subtidal sediment studies and injured species studies (i.e. harlequin duck, etc.). Logistic costs may be reduced for the Kenai and Alaska Peninsula portion by combining resources with the proposed Shoreline Assessment project.

All chemical data from environmental samples will become part of the *Exxon Valdez* oil spill database managed by ABL for the Trustees; as such, data can be shared with interested parties.

FY 95 BUDGET (\$K)

Personnel	265.0
Travel	28.5
Contracts	69.5
Commodities	27.2
Equipment	4.0
Subtotal	394.2
Gen. Admin.	44.6
Total	438.8

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Recovery Monitoring of Prince William Sound Killer Whales

Project Number:	95092
Restoration Category:	Monitoring (continuation of 94092)
Proposed By:	NOAA
Cost FY 95:	\$110,000
Cost FY 96:	\$27,200 (includes data analysis and report writing costs)
Total Cost:	Unknown
Duration:	20 years (monitoring every other year; 10 samples are required to achieve statistically reliable information. If recovery of AB pod to 36 members occurs prior to complete sampling period, project can be terminated.)
Geographic Area:	Prince William Sound
Injured Resource/Service:	Killer whale

INTRODUCTION

Photographs of individual killer whales occurring in Prince William Sound (PWS) were collected from May to September 1989-91 to assess the impact of the EVOS on killer whale abundance and distribution (NRDA studies) and from July to September 1993 to determine the recovery status of AB pod.

Photographic analysis of resident pods revealed 14 animals missing from AB pod over the three-year period (1989-1991). Despite considerable searching effort in PWS (1989-1993), in Southeast Alaska (1989-94), and from the Kenai Peninsula to the Bering Sea (1992 and 1993), the missing whales have not been observed. Given the stability of resident pods, we assume that the missing whales are dead. The mortality rates for AB pod ranged from 3.1% in 1988 to 19.4% in 1989, 20.7% in 1990, and 4.3% in 1991. Zero mortality occurred in 1992 and in 1993. The adult annual mortality rate of killer whales is usually less than 2%. Annual pod mortality rates on the order of 20% are unprecedented for North Pacific killer whales.

The cause(s) of the disappearance of 14 whales from AB pod is unknown; however, we assume that the whales are dead from natural causes, a result of interactions with fisheries, from the EVOS, or a combination of these causes.

No new calves were born into AB pod in 1989 or 1990. There was one calf born into AB pod in 1991, two born in 1992 and one born in 1993. AB pod size in 1988 was 36; in late 1993 the pod had 26 members. The pod appears to be growing again. Recovery of AB pod to pre-spill levels (36 whales) could take 10 to 15 years given the current age and sex structure of the population. Killer whales will have fully recovered when the injured pod grows to at least 36 animals (1988 level).

We propose to continue monitoring AB pod to document natural recovery of this resident killer whale pod. This project will build on the research and monitoring data collected for the years 1989-1991 and 1993.

NEED FOR THE PROJECT

The proposed project on Prince William Sound killer whales will monitor the natural recovery of AB pod. Recovery to a pre-spill level of 36 animals is the restoration objective defined in the "Invitation to Submit Restoration Projects for FY 1995", dated 16 May 1994.

PROJECT DESIGN

A. Objective

1. Count the number and individually identify killer whales within AB pod.
2. Determine killer whale pod structure and integrity within AB pod.
3. Determine killer whale reproductive rates and trends in abundance for AB pod within Prince William Sound.

B. Methods

Weather permitting, an average of 8 to 10 hours per day (six days per week) will be spent conducting boat surveys searching for or photographing whales. If whales are not located in known areas, a general search pattern will be implemented. This search method will consist of running for 30 minutes while scanning for killer whales and then stopping for ten minutes to scan with binoculars and listen for killer whale calls using a hydrophone. This will be repeated until killer whales are either sighted or until the end of the day. When reports of killer whales are received from sport and commercial fishing vessels, tug boats, and State ferries, researchers will break trackline and move to the area where whales are reported.

When encountered, killer whales will be photographed and survey forms completed. The vessel approximates the whale's course and speed. An approach within 30-60 meters of the whales left side is required. The whale's dorsal fin and saddle patch are then photographed with 35 mm camera systems equipped with motor drives and 300 mm lens set at 1/1000th sec shutter speed, or the highest speed possible. Black and white Fuji 1600 film will be used. Exposed film is labeled with date, roll number, photographer's initials, location, species code, and ASA setting.

Multiple encounters are needed throughout the season with AB pod because the pod may temporarily fragment while foraging. Because AB pod members frequently travel with other resident pods (associated with other pods 80% of the time), photographs of all killer whales encountered in Prince William Sound will be collected.

All exposed film will be analyzed for individual identification. Sub-standard photographs (not showing enough detail or improper angle/side) are not used. Photographs are then grouped by individual. Photographs collected will be compared to NMML's photographic database for the years 1989 to 1991 and 1993. Once all photographs are examined, it is then possible to determine 1) if all members of the pod were present, 2) if pod structure and integrity are similar to previous years, and (3) if new whales (calves) were born into the pod. Any missing animals are noted.

Daily effort logs will be maintained. These logs permit a quantification of the amount of time searching for whales versus photographing whales and depicts the daily vessel trackline. Researchers will be required to conduct line transect surveys while searching for whales. This will allow standardization of effort across years -- a requirement for understanding distribution patterns of killer whales. All cetaceans observed during survey work will be listed.

Killer whale calves of the year are identified by size, their mothers identified, and average pod birth rates calculated. Mortality is assumed based on the absence of an identified animal from its pod for more than one year. Due to the proposed sampling strategy (every other year beginning in 1995) it will not be possible to determine mortality the year immediately following the field season. A period of two years will lapse prior to establishing the fate of a missing whale.

C. Schedule

Field Season:	July to September 1995 (every other year)
Data Analysis:	October to December 1995
Draft report of 1995 research:	January 1996
Final report of 1995 research:	March 1996
Comprehensive report:	November 1996

A comprehensive report would be completed every other year beginning in 1996. Data collected for all years beginning in 1989 would be updated pending the results of each field season. As more data are collected, a detailed analyses and subsequent interpretation of existing data can occur. This will lead to a better understanding of the biology and life history of Prince William Sound killer whales.

D. Technical Support

Technical support will be provided by the research/administrative staff of the Alaska Fisheries Science Center, National Marine Mammal Laboratory, Seattle, Washington.

E. Location

Field work conducted under this project will be restricted to Prince William Sound. Laboratory work (data analysis/archiving/reporting) will take place at the National Marine Mammal Laboratory, Seattle, Washington.

PROJECT IMPLEMENTATION

Scientific personnel from the National Marine Mammal Laboratory would implement this project. Scientific/administration staff at the National Marine Mammal Laboratory are thoroughly familiar with all aspects of the proposed research. Previous photographic data associated with killer whale EVOS studies is archived at NMML. Photographic data collected in 1995 would be archived at NMML in a similar manner. NMML has the facilities to properly archive and organize the data to ensure its protection over the years. The accessibility of data is greater if stored at a government facility. By centralizing the data at a government facility, staff at NMML have been able to encourage additional studies of existing information. As an example, studies were conducted on 1) hearing capabilities of killer whales; 2) the effects of noise on killer whales; 3) killer whale aging studies; 4) killer whale foraging and 5) two separate projects are being considered by graduate students. All these studies have been supported by NMML using data collected on killer whales collected during EVOS studies. Research continuity is critical to the overall success of this project; NMML has been involved since the initiation of this project. Since 1989, a critical network has also been established. NMML researchers work closely with other EVOS Principal Investigator thereby ensuring the integration of marine mammal data throughout Prince William Sound. In addition, the National Marine Fisheries Service has a legal research mandate to conduct studies on cetaceans and a mandate to manage populations under the Marine Mammal Protection Act.

COORDINATION OF INTEGRATED RESEARCH EFFORT

All EVOS project leaders conducting field research in Prince William Sound will be contacted by the Principal Investigator of the killer whale study. A brief killer whale project description will be provided to each Project Leader. We will encourage other research teams to provide

sighting information (on a not-to-interfere basis with their ongoing work). We will also routinely contact other Project Leaders to obtain information on current fisheries information. This fisheries information may be relative to the recovery rates of killer whales. If the monitoring project on killer whales is merged with the killer whale predation project on harbor seals being proposed by NMML, coordination on a much larger scale occurs.

FY 95 BUDGET (\$K)

Personnel	23.0
Travel	6.0
Contractual	50.0
Commodities	24.0
Equipment	0.0
Subtotal	103.0
Gen. Admin.	7.0
Total	110.0

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Administration, Public Information and Science Management

Project Number:	95100
Restoration Category:	Administration, Public Information and Science Management
Proposed By:	James R. Ayers, Executive Director <i>Exxon Valdez</i> Oil Spill Trustee Council
Cost FY 95:	\$3,596,900
Cost FY 96:	\$3,500,000
Total Cost:	Unknown
Duration:	Ongoing (this project funds the annual operating costs of the Trustee Council's restoration program)
Geographic Area:	Oil spill area
Injured Resource/Service:	Multiple resources and services

INTRODUCTION

The Administration, Public Information and Science Management project provides for overall management, administration and implementation of the Trustee Council's restoration program. This project makes extensive use of existing Trustee Council agency structures to keep administrative costs to a minimum.

The proposed FY 95 budget of \$3,596,900 for Administration, Public Information and Science Management represents a substantial reduction in costs relative to the FY 94 budget of \$4,200,000. The FY 95 project represents the final step in reorganization of the administration of the Trustee Council executive staff and operations. Specific components of the Administration, Public Information & Science Management project include:

Office of the Executive Director — The budget for the Executive Director includes salaries, benefits, travel, office space, supplies, printing costs, contractual services, utilities, and other such items as may be necessary for efficient operation of the Juneau office of the Executive Director and the Director of Administration. In addition to budget and audit responsibilities, the Director of Administration is assuming the duties once performed by the six-member Finance Committee: developing fiscal procedures, adherence to the procedures, and ensuring overall fiscal standards and reporting for accountability, and efficiency.

Chief Scientist: Science Review Board and Peer Review — The Trustee Council and the Trustee Council-supported principal investigators need access to the best possible scientific knowledge and understanding concerning injured resources and services. This information has been provided continuously by the Chief Scientist and expert peer reviewers since the injury assessment process started in 1989. It is essential that this expertise be retained on an upon-request basis to provide the unbiased scientific review and continuity essential to perform the best possible scientific work. This component will also include the Science Review Board, when adopted by the Trustee Council.

Operations — The budget for Operations includes salaries, benefits and travel for staff that perform the key planning, coordination, communications and project management functions of the Trustee Council. This budget also includes funds for public meetings, teleconferences, Trustee Council meetings, newsletters, brochures and other publications, as well as the operating costs for offices in the Simpson Building in Anchorage.

Public Advisory Group and Community Involvement — The Public Advisory Group (PAG) consists of 17 members, plus two ad-hoc members from the State Legislature, representing 12 principal interest groups and five members from the public-at-large. The role of the PAG is to provide advice to the Trustee Council on such items as the annual work plans, budgets, and the Restoration Plan. The budget reflects the administrative support expenses for the PAG, including staff support, which is now being provided through the state in order to provide more user-friendly travel reimbursement. In addition, this component provides for a series of public meetings throughout the spill area during the year.

Restoration Work Force — The FY 95 budget for the Restoration Work Force reflects support for the six Trustees with a budget of \$150,000 per Trustee Council agency. This funding will be used to support staff who function as agency liaisons. These liaisons serve as overseers of work plan development and generally represent the Trustee Council members in matters related to implementation of the restoration program. (Agencies also receive funding for project management in association with individual projects.) Costs involved are salaries, benefits, travel, per diem, equipment and commodities.

NEED FOR THE PROJECT

The project will provide the essential management and administration necessary to efficiently implement the restoration program developed by the Trustee Council.

PROJECT DESIGN

A. Objectives

The fundamental objective of the Administration, Public Information and Science Management project is implementation and management of the Trustee Council's direction to pursue a comprehensive, balanced approach to restoration built upon three basic elements:

- Research and Monitoring
- General Restoration
- Habitat Protection

Specific objectives for FY 95 include:

1. Implementation of a Final Restoration Plan, pending completion of the NEPA Environmental Impact Statement process;
2. Implementation of the approved FY 95 Work Plan;
3. Continued oversight and management of the Trustee Council science program that includes the peer review and project evaluation process under the direction of the Chief Scientist as well as development of a Science Review Board;
4. Sponsorship of an Annual Forum that brings together scientists, agency staff, Trustee Council staff and members of the general public to review the status of injured resources and services and help devise and refine appropriate restoration strategies through an adaptive management process;
5. Further refinement of draft monitoring strategies for injured resources;
6. Further habitat evaluation, appraisals and negotiation with potentially willing sellers as part of both the Large Parcel and Small Parcel Habitat Protection Programs;
7. Continued work on the proposed physical improvements to the Institute of Marine Science facilities in Seward;
8. Regular meetings and interaction with the Public Advisory Group (PAG) as one means of gathering public input into the Trustee Council process;
9. Production of an Annual Report;
10. Publication of a newsletter six times/year regarding activities of the Trustee Council;
11. Development of the FY 96 Work Plan, including opportunity for substantial public involvement and review of the work plan;

12. Oversight and management of the Trustee Council's FY 92-95 Work Plan projects and expenditures, including the production of quarterly reports that track the status of Trustee Council authorized projects;
13. Completion of a financial audit; and
14. Development of an inventory tracking system.

B. Methods

All Trustee Council operations are governed by the state and federal laws and regulations that apply to the respective agencies that comprise the Trustee Council.

C. Schedule

The Trustee Council operates on the federal fiscal year (Sept 30 - Oct 1).

D. Technical Support

Trustee Council operations require limited technical support with computer support services provided by in-house staff.

E. Location

The Trustee Council maintains the Executive Director's Office in Juneau (709 west 9th Street, Juneau, Alaska, 99801) and a Restoration Office in Anchorage (645 G Street, Anchorage, 99501).

PROJECT IMPLEMENTATION

The Trustee Council, established under the terms of a court approved civil settlement, is comprised of the Commissioner of the Department of Environmental Conservation, the Commissioner of the Department of Fish and Game; the Attorney General of the State of Alaska; the Secretary of the Department of the Interior; the Secretary of the Department of Agriculture; and the Director of the National Oceanic and Atmospheric Administration. In order to manage the Settlement as directed by the Trustee Council, an Executive Director has been hired who oversees a small core staff while making use of existing Trustee Council's agency structures to keep administrative costs to a minimum.

COORDINATION OF INTEGRATED RESEARCH EFFORT

As part of an adaptive management process, the Trustee Council will sponsor an Annual Forum that will bring together scientists, agency staff, Trustee Council staff and members of the general public to review the status of injured resources and services and help devise and refine appropriate restoration strategies. This is one mechanism by which research sponsored by the Trustee Council will be coordinated and integrated. Additionally, during FY 95, a Science Review Board will be established and used as a mechanism to provide overall coordination and integration of the Trustee Council science program.

FY 95 BUDGET (\$K)

Personnel	1811.0
Travel	268.5
Contractual	1108.5
Commodities	70.4
Equipment	30.5
Subtotal	3288.9
Gen. Admin.	308.0
Total	3596.9

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Kenai River Ecosystem Restoration Pilot Enclosure Study

Project Number:	95105
Restoration Category:	General Restoration (new)
Proposed By:	ADFG
Cooperating Agency:	DOI
Cost FY 95:	\$404,800
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Skilak Lake, Kenai Peninsula
Injured Resource/Service:	Sockeye salmon, commercial fishing

INTRODUCTION

This study stems from the results of the 1989 *Exxon Valdez* oil spill (EVOS). During the summer of 1989, the presence of oil in the waters of Cook Inlet resulted in an overabundance of sockeye salmon escaping into the Kenai River system. The injury assessment of the Kenai River ecosystem has focused on changes to production of sockeye salmon caused by large escapements. This study is an extension of ongoing investigations of injury assessment of the Kenai River ecosystem with emphasis on productivity of sockeye salmon. This study will initiate a pilot restoration project using enclosures in Skilak Lake to provide an experimental design to determine possible restoration strategies. The enclosure studies will allow experimental manipulation of fish density and nutrients on a limited scale to determine the costs and benefits of larger scale programs, such as changing fry recruitment through escapement changes, or nutrient additions to simulate fish carcass decomposition. This program emphasizes a cooperative State/Federal involvement to insure goals are designed to meet restorative objectives of both the Alaska Department of Fish and Game and the concerns of the Kenai National Wildlife Refuge. The presence of the Fish and Wildlife Service personnel at Skilak Lake throughout the summer in the course of normal refuge operations provides the opportunity for cost effective management of the enclosures. In addition, the expertise in sockeye salmon studies of the National Biological Survey research laboratory (formerly US Fish and Wildlife Service) in Anchorage provides additional local expertise and facilities.

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, that rear in lakes for one or two years, serve as a food source for a variety of birds, 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 one 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. In general, when rearing fish abundance greatly exceeds the lake's carrying capacity, prey resources are altered by changes in species and size composition with concomitant effects on all trophic levels. Because of such changes, juvenile sockeye growth is reduced, mortality increases, larger percentages holdover for another year of rearing; and the poor quality and small size of smolts decreases 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. This is the brood-year interaction underlying cyclic variation in the year class strength of anadromous fish. Recent findings from the Kenai River drainage suggest major economic injury to commercial, subsistence, and sport fisheries may result because of overescapement associated with fisheries closures caused by the 1989 oil spill. Smolt numbers emigrating from the Kenai River in the spring of 1992 and 1993 were less than one-fiftieth the numbers estimated in 1989. This suggests a likely possibility of future returns below existing escapement goals.

Recent studies on the Kenai River system indicate Skilak Lake fall fry are significantly smaller than nearby Tustumena Lake, a system that had normal escapements during the past decade. Data collected in 1993 suggest this trend has continued; Tustumena Lake fall fry were significantly larger than Skilak Lake. The estimated abundance of fall fry compared with total smolt estimates for Tustumena and Skilak lakes imply that the overwintering period resulted in major mortality of rearing fry in Skilak. We have also discovered an inverse relationship of egg-bearing *Diaptomid* copepods with fry abundance in Skilak Lake suggesting selective depletion of this food resource. Nutrient data does not suggest nutrient depletion as the major cause of the decline of sockeye salmon in Skilak Lake. However, the low values of reactive phosphorous in the lake (less than $5 \mu\text{g l}^{-1}$) suggest nutrients may be limiting, and may have some potential for accelerating the recovery of the system. Nutrient additions have been used in many Alaskan and Canadian sockeye salmon systems to improve productivity of oligotrophic systems by simulating the natural nutrient supplementation achieved through salmon carcasses.

However, glacial lakes have had limited investigations, and there is limited understanding of the ecosystem dynamics of nutrient cycling in glacial lakes.

NEED FOR THE PROJECT

Restoration activities potentially possible for the Kenai River include adjustment of escapement levels, enhanced egg to fry survival through hatchery fry production, barren system stocking, smolt stocking and nutrient enrichment. All of these activities have potential to cause harm if improperly applied. The proposed project will provide experimental evidence as to the efficacy of some of these activities. Without such a program, we may face continued uncertainty as to what action to take in the future to restore the Kenai River sockeye salmon runs.

Injury assessment investigations to date have provided inferences as to the causal mechanism of the decline of sockeye salmon production from the Kenai River ecosystem. Although correlative studies and comparisons of results from neighboring Tustumena Lake provide valuable insights, major uncertainty remains because of the lack of true controls and replicates inherent in the study design used to date. Without bold experimental manipulations of the affected lakes through major changes of escapement or by whole lake nutrient enrichment programs, the development of a restoration plan with any reasonable expectation of success is unlikely. The use of enclosures, with the treatments outlined in this proposal are much more likely to provide insights as to what should be the future restorative actions without the biological, economic, and political risks associated with large-scale restorative activities within the Kenai River lake ecosystems. By understanding the mechanism which caused the collapse in sockeye salmon smolt production in the Kenai River system, valuable information will be available for fisheries management of the future. The resources affected have had annual economic value in excess of \$100 million dollars in direct commercial value and have had major economic benefit to the sport fishing industry, and importance to subsistence and personal use fishers on the Kenai Peninsula. The forecasted decline has shown no sign of recovery. The investment in knowledge on glacial lake ecology will also provide benefits to other sockeye salmon investigations, such as the glacially influenced Coghill Lake in Prince William Sound.

PROJECT DESIGN

This study will be located within Skilak Lake on the Kenai Peninsula. Specific locations of the enclosures will be chosen to minimize conflict with public users and through the permitting and cooperative effort of the Kenai National Wildlife Refuge Staff. The proposed study will be conducted for a minimum of two growing seasons (years).

A. Objectives

1. Test hypothesis of altered vertical migration by comparing vertical movement of fish and zooplankton within enclosures (a through d below) and with samples collected external to enclosures (pelagic lake samples).
2. Determine top down trophic level response by comparison of zooplankton and phytoplankton community compositions and biomass with enclosure treatments (a through d below) and with samples collected external to enclosures (pelagic lake samples).
3. Determine bottom up trophic level response by comparison of nutrient flux and phytoplankton, zooplankton, and fish composition and biomass responses to nutrient additions (enclosures c and d) with controls and other non-nutrient treatments.
4. Integrate the results of the enclosure studies to the time series of data collected from Skilak, Tustumena, and Kenai lakes in formulating optimal restoration strategies for these systems.

Enclosure types in replicate:

- a. Fish removed from enclosure (no treatments or fish added).
- b. Fish added to approximate densities observed in the western basin of Skilak Lake.
- c. Nutrients added to simulate optimal phosphorous and nitrogen nutrient loading (fish excluded) using nutrient loading models developed for Alaskan and Canadian sockeye salmon lakes.
- d. Nutrient additions to simulate optimal phosphorous and nitrogen loading and fish added to approximate densities observed in the western basin of Skilak Lake (treatment b & c combined).

B. Methods

These studies will be conducted concurrently with ongoing investigations of the biotic communities of Skilak, Kenai, and Tustumena lakes (proposed 1994 sockeye salmon overescapement work plan). These studies have provided insight into the apparent collapse of the Kenai River sockeye salmon fishery over the past several years. Since over 70% of the sockeye salmon production in the Kenai River system has been produced from fry rearing in Skilak Lake, this system is chosen for further experimental studies.

Enclosures will be deployed in a protected area in Skilak Lake, with the location developed jointly with the U.S. Fish & Wildlife Service. Eight enclosures of approximate 8 m diameter and a depth of approximately 25 m will be deployed using four replicate treatments following the design (2 X 2 factorial) of Mazumder et al. In addition, samples will be collected external to the enclosures for comparative control on the effect of enclosures and comparisons will be made with the other ongoing limnological studies of Kenai, Skilak, and Tustumena lakes. Fish added to the enclosures will be collected from the pelagic zone of Skilak Lake in late

June/early July and will be less than 35 mm FL.

The enclosures will be sampled biweekly and the data analyzed similar to the methods used for the open water studies with modifications from Mazumder et al. These will include seasonal nutrient trends, water temperature, turbidity, phytoplankton community analysis, chlorophyll *a*, zooplankton community composition and biomass, fish AWL (age, weight, lipid content, length) and other water chemistry parameters. These data will be analyzed to measure bottom up and top down lake ecosystem control mechanisms and will be used to better interpret inter-annual variations in lake limnological parameters. This analysis will provide insight as to the most effective strategies to initiate in the lake for restoring lost or reduced productivity of sockeye salmon to this freshwater ecosystem.

C. Schedule

Although desired to be implemented in the spring of 1994, logistical planning may make this impossible. Enclosure design and construction will require customized modifications to insure the enclosures can be deployed in the conditions anticipated in Skilak Lake. Enclosures will be obtained through State of Alaska procurement procedures which may result in delays of implementation until the spring of 1995. The enclosures will be deployed as soon as we receive them from the manufacturer. Data obtained through monitoring of the Kenai River system lakes will be used to fine tune study design if deployment is delayed to the spring of 1995.

Laboratory analysis of field samples continues 12 months a year and will be in progress throughout the study period. This analysis includes samples of zooplankton, water chemistry, juvenile fish scales and otoliths, weight/length of juvenile fish, lipid and N15 from juvenile fish.

Field data collection efforts begin in mid April for field deployment in May. Data are collected throughout the summer and terminated when the lakes form an ice cover at approximately December 1st. The weight and lipid content of fish in the enclosures will be determined by lethal sampling in September. Sampling of vertical distribution of fish, zooplankton, and related water quality and physical data are collected at preset intervals throughout the summer. Reporting activities and data summarization continues throughout the year with the primary effort occurring in September through December with interim reports completed by May 15th of each year of the study. Final report for this study will be completed by June 1, after the completion of the final year of field work. Tentative completion date for this study will be June 1, 1996.

Initiate field studies	May 1995
Complete field studies	December 1996
Draft Report for FY 94	March 1996
Final Report	June 1997

D. Technical Support

Administrative support is provided by the Administrative Division, Habitat Division, and Commercial Fisheries Management and Development Division staff of the Alaska Department of Fish and Game. The project leader and his assistants are not funded by this project and are supported with general funds from the State of Alaska. Most laboratory analyses are conducted by the limnology laboratory in Soldotna. Carl Burger (National Biological Survey) will assist with data analysis and report publication preparation. Asit Mazumder of the Universite de Montreal will be contracted as a consultant in the design and analyses of this study with assistance from graduate or post-doctoral students under his direction. Dr. Mazumder has over a decade of experience in these types of investigations on northern lakes. This study is integrated with ongoing studies by the Commercial Fisheries Management and Development Division on the Kenai Peninsula.

E. Location

The investigations will occur on Skilak lake on the Kenai Peninsula. Specific locations will be developed through a coordinated effort with NBS and the US Fish and Wildlife service staff in Soldotna. The locations will be chosen that meet technical objectives without intruding upon normal use patterns of the Kenai National Wildlife Refuge.

PROJECT IMPLEMENTATION

The project is integrated with the ongoing studies of the limnology of Skilak Lake. Special use permits, sources of fish for the enclosures, and the integration of the lake studies with the experiments require the work to be integrated with these studies. The deployment of this type of equipment and its design require a great deal of scrutiny in sight selection and enclosure engineering. There are only several experts in North American who have had adequate experience with these types of studies to provide the necessary technical guidance to insure a high probability of success. For the results to be comparable, laboratory and chemistry analyses should be done with the same facilities used in the Skilak Lake limnology studies. The dangerous conditions on Skilak Lake require some on sight experience to avoid danger to participating personnel. Experienced divers in low visibility will also be required to install the enclosures. These reasons suggest that this investigation be awarded to the same contractor or agency completing the Skilak Lake limnology studies.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This study requires on-site data collection of biological specimens both within and external to the enclosures; however no environmental effect will occur beyond that of traditional fisheries management data collection, that is within existing collecting permits or Federal special use permits issued to the Department of Fish and Game for scientific data collection activities. A special use permit will be requested through our cooperative agency, the U.S. Fish and Wildlife Service, prior to deployment of the enclosures. These studies will be closely integrated with the lake limnological studies and fry rearing investigations conducted by the same authors.

FY 95 BUDGET (\$K)

Personnel	106.0
Travel	9.3
Contractual	206.7
Commodities	37.5
Equipment	15.0
Subtotal	374.5
Gen. Admin.	30.4
Total	404.8

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Subtidal Monitoring: Eelgrass Communities

Project Number:	95106
Restoration Category:	Monitoring (new)
Proposed By:	ADFG
Cost FY 95:	\$200,400
Cost FY 96:	\$432,100
Total Cost:	\$632,500
Duration:	2 years
Geographic Area:	Western Prince William Sound
Injured Resource/Service:	Subtidal organisms

INTRODUCTION

The shallow subtidal habitats of Prince William Sound, from the intertidal zone to depths of approximately 20 m, typically has dense macrophyte or sea grass assemblages, and is critical habitat for many commercially and ecologically important animals. Subtidal eelgrass beds contain numerous polychaete worms, small snails and clams, amphipods, isopods, sea urchins, and sea stars, many of which serve as food for coastal-feeding otters, birds, and fishes.

The subtidal eelgrass community was one of the several habitats examined relative to *Exxon Valdez* Oil Spill (EVOS) effects and subsequent recovery. Investigations comparing oiled-control sites in this habitat were conducted in 1990, 1991 and 1993 and are summarized below (no sampling occurred in 1992).

1990: Almost all components of the eelgrass habitat were affected by the EVOS by the summer of 1990. The health of the benthic community outside the eelgrass bed, at 6-20 m depths, was generally less robust at oiled sites than at control sites. The oiled sites had significantly less total invertebrate abundance; several dominant invertebrate taxa had less abundance and/or biomass. These included families of clams that are important food for sea otters. Another group less prevalent at oiled sites were the oil-sensitive benthic amphipods. Measured parameters less prevalent at the oiled sites in the eelgrass bed (≤ 3 m) included eelgrass turions and flowers, benthic amphipods, and helmet crabs (*Telmessus cheiragonus*). However, the benthic community in the bed had greater total invertebrate abundance and biomass at the oiled sites, primarily attributable to small epifauna attached to the eelgrass blades.

1991: The 1991 data revealed partial recovery. Outside the eelgrass bed (6-20 m) oiled sites were more similar to control sites than in 1990. The greatest indication of recovery was with benthic amphipods which revealed no differences between oiled and control treatment groups. Within the bed (≤ 3 m), no differences were now evident in density of eelgrass turions or flowers, benthic amphipods, and helmet crabs. However, several of the dominant taxa had lower abundance or biomass at oiled bed sites, indicative that recovery was lagging within the eelgrass bed.

1993: The 1993 data, four years after EVOS, revealed that the oiled sites had not yet recovered. Furthermore, the data tended to resemble 1990, especially in the bed (≤ 3 m) where densities of eelgrass flowers and oil-sensitive benthic amphipods were greater at control sites. Total abundance and biomass was greater at oiled sites, mainly because of small epifauna attached to the eelgrass blades. In the deep region (6-20 m) infaunal bivalve abundance was less at oiled sites.

After the 1991 sampling it was apparent that recovery was underway, however, the 1993 data reveals a reversal, suggesting that some segments of the community are once again in a toxic phase (e.g., amphipods) and other segments reflect enhancement (e.g., epifauna on eelgrass).

We know from other studies and from our work that several of the species impacted are important links to higher trophic levels. For example, benthic amphipods are important prey to a variety of sea birds and fishes. The crab *Telmessus* feeds on eelgrass, *Musculus* mussels, and other epiphytes on eelgrass. In turn, *Telmessus* serves as prey for a variety of vertebrates, including sea otters, river otters, and birds. In addition, *Musculus* is a primary component of the diet of juvenile cod that are abundant in the eelgrass habitat. As noted earlier, some of the infaunal bivalves are important food for sea otters.

NEED FOR THE PROJECT

Since no sampling occurred in 1994, and since community recovery had not occurred through the 1993 sampling, it is advisable to reexamine these eelgrass sites again in 1995 to monitor recovery.

PROJECT DESIGN

A. Objective

The objective is to monitor the natural recovery of the shallow (< 20 m) subtidal eelgrass community in Prince William Sound that was impacted by the EVOS by spatially comparing richness, diversity, abundance and biomass of dominant taxa between paired (oiled:control) sites.

B. Methods

Our approach for 1995 is to monitor the various successional stages of the eelgrass community toward stabilization by comparing components of oiled and unoiled sites in a stratified sampling design. We will again sample the sites that were sampled in 1990, 1991 and 1993. Sampling will be conducted at four oiled and control eelgrass sites. Methods will be the same as was previously used in this project. Within this habitat we will determine estimates of abundance/biomass of eelgrass, infauna, small epifauna attached to eelgrass, amphipods, large epifauna (i.e., crabs and sea stars), and juvenile Pacific cod. These estimates will be used to indicate the effects of the EVOS on this community by comparing abundance (and other parameters) at oiled vs. control sites.

C. Schedule

July 1995	Field activities are planned for two weeks during this time to correspond with previous samplings
Dec. 1995	Completion of laboratory processing of samples
Feb. 1996	Completion of draft final report

D. Technical Support

A research vessel is needed for two weeks of diver sampling. In addition, two skiffs will be needed to assist in the field operations. Inflatable boats (14 ft) with 30 hp outboards has functioned best in past field efforts. These should be provided by ADFG or the vessel subcontractor.

E. Location

A total of four oiled sites and four control sites have been selected from those we previously studied in western Prince William Sound. Sampling will occur at the following oil/control paired sites: Bay of Isles (O)/Drier Bay (C); Herring Bay (O)/Lower Herring Bay (C); and Sleepy Bay (O)/Moose Lips Bay (C); Clammy Bay (O)/ Puffin Bay (C).

PROJECT IMPLEMENTATION

This project has been implemented by ADFG for the past three years.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is closely linked to the monitoring of oil in subtidal (< 20 m) sediments (conducted by NOAA). Several study sites are in common between the two projects.

FY 95 BUDGET (\$K)

Personnel	6.0
Travel	0.0
Contractual	180.8
Commodities	0.0
Equipment	0.0
Subtotal	186.8
Gen. Admin.	13.6
Total	200.4

Sound Waste Management Plan

Project Number:	95115
Restoration Category:	General Restoration (new)
Proposed By:	Prince William Sound Economic Development Council
Lead Trustee Agency:	ADEC
Cost FY 95:	\$352,200
Cost FY 96:	\$66,500
Total Cost:	Unknown
Duration:	Unknown
Geographic Area:	Prince William Sound
Injured Resource/Service:	Intertidal and subtidal organisms, and other injured resources and services that are dependent upon clean marine waters

INTRODUCTION

The Sound Waste Management Plan (SWMP) is a comprehensive plan to identify and remove existing oily and other solid waste from the waste stream, of the oil-impacted communities of Prince William Sound. The plan will improve upon current waste management and join past efforts into a unified regional effort. The SWMP, will put into action an oily and solid waste management system that will operate in all Prince William Sound communities to eliminate the potential for further encroachment or damage to the local ecosystem.

Problem: Currently each community in Prince William Sound is out of compliance with federal regulations as it relates to permitting of waste sites. There are no regional goals for managing, reducing and handling of oily and solid waste. Because there is no plan, Prince William Sound is at a potential risk to further environmental harm. Prince William Sound Economic Development Council's regional Solid Waste Management Committee was formed, therefore, as a task force of the area's largest contributors of waste. This included both cities, villages,

industry, and hatchery representatives. They identified the following regional problems:

1. Costs to manage and handle oily and solid waste continue to rise and tap declining revenue resources.
2. Existing landfills have limited life spans.
3. There is no long term solution in sight.

Solution: A three phase approach is needed to: 1. identify 2. reduce the cost of handling oily and solid waste, and 3. implement an oily and solid waste management plan.

- Phase I will identify the options and most cost-effective means for handling and managing oily and solid waste in Prince William Sound. The PWSEDC regional committee will contract a firm to accomplish this phase;
- Phase II will handle all required ADEC/EPA permitting to implement a regional management project; and
- Phase III is the implementation of the SWMP that includes construction of the identified, chosen project i.e. regional landfill, regional incineration, etc.

It is important to note that as a regional project, local input and coordination is crucial to the long-term success of the SWMP project by creating local ownership. This proposal was developed and intended to be coordinated by PWSEDC's Solid Waste Management Committee in cooperation with ADEC.

The EVOS Trustee Council has funded a similar project, number 94417 entitled "waste oil disposal facilities." The SWMP broadens that project approach and greatly increases the effectiveness of enhancement and restoration efforts due to its regional coverage, local expertise and long term monitoring.

Funding for SWMP will allow an effective and necessary approach to enhancement, clean-up and collection of valuable data as it relates to oily and solid waste management in Prince William Sound in 1995. The SWMP will restore, enhance and promote long-term preservation of Prince William Sound from the effects of oily and solid waste. This document describes the plan of work to be undertaken during FY '95

NEED FOR THE PROJECT

To further enhance, improve the rate of natural recovery of, and reduce future events of marine pollution in Prince William Sound, the SWMP, is crucial. To ensure the protection and preservation of the Prince William Sound oil-impacted region, implementation of this plan is needed. Under EVOS Designated Wilderness Area objectives, "any restoration objective which aids recovery of injured resources, or prevents further injuries, will assist recovery of these areas." This is the SWMP focus.

The current primary waste stream for oily waste are local harbors. From boats, both domestic waste water (sewage) and oily waste are discharged directly into Prince William Sound. The secondary stream is smaller in direct amounts, but no less damaging to the oil-impacted environment. This includes leachates from community landfills that contribute to the total impact of waste to the local ecosystem. To add to this, all area landfills in Prince William Sound including both cities and villages are out of compliance with federal regulations. The SWMP is the only regional effort identified to date that could provide a solution to oily and solid waste management in Prince William Sound.

PROJECT DESIGN

A. Objectives

The development of the Sound Waste Management Plan (SWMP) originated with Prince William Sound Economic Development Council's regional Solid Waste Management Committee. The primary objectives include the development and implementation of a regional strategy to limit the exposure of hazardous waste material in oil-impacted communities in Prince William Sound. The SWMP will provide a design and recommend an oily and solid waste collection and disposal alternative and provide a plan for future management of oily and solid waste in Prince William Sound. The following outlines the objectives to be accomplished in FY '95:

1. Gather background information on the composition and rate of oily and solid waste generation in Prince William Sound
2. Analyze waste management processing and disposal alternatives and select the most appropriate solution for Prince William Sound
3. Address regulatory requirements
4. Establish public participation program to understand and address community concerns and needs
5. Analyze oily and solid waste reduction and recycling options
6. Evaluate sites for a new regional landfill
7. Develop cost estimates for oily and solid waste management alternatives
8. Recommend financial planning to fund oily and solid waste services

B. Methods

The SWMP will include a scoping of the current Prince William Sound situation by qualified firm. This scoping will determine both the options and costs related to each in implementing a regional oily and solid waste management system.

C. Schedule (FY 95 - Plan of Work)**Phase I**

Nov 1, 1994	Distribute Request for Proposals (RFP's) for regional oily and solid waste management plan.
Dec 1	Coordinating meeting (Review of submitted proposals)
Jan 1995	Select consulting firm and draft contract
Feb 1	Coordinating meeting (contractor and committee)
Mar 1	Review of scoping firm's draft plan findings with PWSEDC Solid Waste Committee comments.
Apr 1	Public Review of findings (held in each PWS community)
Apr 2	Determination of most efficient and cost effective regional oily and solid waste system.

Phase II

Apr 1, 1995	Start process for implementation of regional oily and solid waste system.
Apr 15	Scope ADEC/EPA permitting for project implementation
Jun 1	Committee review and evaluation of FY 95 Work Plan.
July 15	Meeting to review draft ADEC/EPA permits
Aug 15	Submit ADEC/EPA permit
Oct 1	Meeting with ADEC/EPA about questions on permit
Nov 1	Submit revised permit
Jan 1996	Coordinating meeting

Phase III

May 1	Initiate construction of permitted facility
Aug 1	Facility complete and operational

D. Technical Support

Prince William Sound Economic Development Council's Solid Waste Management Committee will play both an evaluative and advisory role to the scoping firm.

E. Location

Prince William Sound

PROJECT IMPLEMENTATION

To maintain the direct link from development and implementation of the SWMP, Prince William Sound Economic Development Council's regional Solid Waste Management Committee is the only appropriate entity to implement this regional project. Alaska Department of Environmental Conservation will additionally play an advisory, and coordinating role with the Committee's efforts.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The SWMP program is a coordinated effort of the Prince William Sound Economic Development Council in cooperation with: Department of Environmental Conservation, Alyeska Pipeline Service Company, Chugachmiut, Valdez Fisheries Development Association, Prince William Sound Aquaculture Corporation, Prince William Sound Conservation Alliance, the City of Valdez, the City of Whittier, the City of Cordova, and the Villages of Tatitlek and Chenega.

FY 95 BUDGET (\$K)

Personnel	34.4
Travel	7.2
Contractual	285.3
Commodities	2.0
Equipment	0.0
Subtotal	328.9
Gen. Admin.	23.4
Total	352.2

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Harbor Seals and EVOS: Blubber and Lipids as Indices of Food Limitation

Project Number:	95117-BAA
Restoration Category:	Research (new)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	NOAA
Cost FY 95:	\$94,400
Cost FY 96:	\$74,500
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Prince William Sound and northern Gulf of Alaska
Injured Resource/Service:	Harbor seal

INTRODUCTION

This proposal is written in collaboration with the inter-disciplinary and integrative Marine Mammal Ecosystems program submission to EVOS. As outlined under the broad program direction, the goals of the combined collaborative projects are to investigate ecosystem wide questions addressing the recovery of marine mammal injured species, specifically, harbor seals. These issues include the direct impact of oil spills, human interactions, food, competition, climatic factors, disease and habitat loss.

Under these guidelines, the enclosed proposal deals with the issues of body condition and health status of harbor seals with the resulting data applying directly to issues of disease, food limitation and the impact of oil.

In collaboration with other field teams, 30-40 harbor seals will be captured and temporarily held at sampling sites within and outside the EVOS area. Complete body morphometrics (to assess body condition) and samples of blood (to examine disease/health status) will be collected. Seals will be returned unharmed to the capture site and blood samples will be taken to the University of Alaska in Fairbanks for analysis.

Body Morphometrics: Using a large temporal and geographic data base currently held at UAF, the body morphometrics of the harbor seals will be analyzed and fit to models of body condition. For example, we have excellent data relating the length and girth of seals to their

body mass. By fitting harbor seals to these curves, we can assess whether the animals are underweight (malnourished) or "normal". Additional factors, such as estimates of total body fat and body density, are included in these assessments of condition. It is proposed that by comparing values for body condition from harbor seals collected before and after the EVOS event and by comparing data collected from animals inside and outside of the EVOS area, we can provide information as to whether this species, which is not recovering, appears to be physically sound.

Blood Chemistry: Samples of blood will be analyzed for over 30 indicators of "health". These tests will examine, among others, potential anemia, dehydration, organ function, tissue damage and oxygen carrying capacity. In addition, assays for hormonal balance and stress protein levels that are extremely sensitive to alterations in health status will be conducted. These data will be compared, on a temporal basis with samples collected before EVOS and on a geographic basis with control animals that were not impacted.

NEED FOR THE PROJECT

As a component of the Marine Mammal Ecosystems proposal, this project deals with the health status/disease/body condition segment of harbor seal biology. To move towards the restoration of marine mammals, a multi-disciplinary, integrative approach is critical given the scope of the problem. Thus, certain components of the Marine Mammal Ecosystems group will focus on habitat use and trophic level interactions, others on population studies and others on food resources. Any one agency cannot handle all components of such an intense approach. The University can provide the services and research for the health component through the Institute of Marine Science marine mammal physiology group. To move towards restoration, interactive projects, such as the one proposed here, must be carried out in collaboration with monitoring programs. That is, limited field programs that only contained a monitoring component or conversely only looked at individual animals would not be the most appropriate way to understand the impact of the EVOS event on injured species.

The premises and hypotheses of this project are simple: Either the EVOS impacted animals are different in their health status compared to non-EVOS animals, or they are not. If the species are compromised, then we will know some of the directions that would have to be followed towards potential restoration. If they are not compromised, then we will be able to focus our attention into other areas that may better explain their current recovery status.

PROJECT DESIGN

A. Objectives

1. Capture 30-40 harbor seals at locations throughout PWS at two to three different times per year. This work will be in direct field collaboration with ADFG.
2. Hold animals for 1-4 hours during which time complete body measurements and blood samples will be collected.
3. Analyze body measurements via computer modeling and assay blood samples for health indicators.

B. Methods

Captures: This will involve procedures tested in the field and routinely utilized by ADFG. Basically, the seals are approached from sea on small boats while the animals are hauled out on beaches. A net is set across the beach and the animals move from the beach into water when they see the boats. Animals are caught in the nets, moved onto the beach, tranquilized to facilitate the measurements and held until all sampling, attachment of diving recorders and recovery from anaesthesia are completed.

Body measurements: Linear and curvilinear length, girth at seven locations and mass are collected from each animal. These are quickly and easily carried out in the field. Back at UAF, the data are fit into models of how length, girth and mass are related for harbor seals and animals are quickly placed above or below their predicted weight for size. In addition, estimates of total body fat will be collected from measurements of total body impedance (BIA). This method utilizes a quick assessment of body fat by measuring resistance across a set of electrodes placed at the head and tail of the body. Further estimates of body fat are taken from ultrasound measurements of blubber depth at half a dozen sites across the body. From all of these values, estimates of body density (ie, relative fatness) can be evaluated.

Blood chemistry: Blood samples are measured in the field to assess the number of red cells in the blood (hematocrit), visualized under microscopes to examine the types of blood cells and then prepared for return to the lab. At Fairbanks, the samples are sent to a veterinary laboratory for assessment of "standard" health indices (such as cholesterol level, salts, and enzymes characteristic of tissue damage) and also analyzed at UAF for indicators of dehydration (water content), malnutrition (BUN, ketones), stress (haptoglobin), hormone imbalance (Angiotensin, ANP) and stress proteins (samples sent to collaborators at Stanford Research Institute). These data can then be compared to cataloged values for healthy seals to assess the status of the PWS seals.

It should be emphasized that the above methods are routine for the marine mammal group at UAF and that we conduct similar assays hundreds of times/year on seal and sea lion species from around the world. Thus, we have the expertise, the data bases and the consistency to best analyze these samples from the PWS animals.

C. Schedule

Capture dates: It is anticipated that captures of harbor seals will occur in the spring (April), summer (July) and fall (October) for both calendar years 1995 and 1996.

Analysis dates: Blood samples will be analyzed after each capture. Some of the assays are rapid and can be done within days for all samples, others take much longer. Body morphometric analysis is rapid and animals can be quickly assessed.

Report dates: The last predicted field season will be in the fall of 1996 and the final section of support will be to allow completion of analyses and publish reports. A final report will be submitted on 12/31/97.

D. Technical Support

Veterinary samples will be sent on a service agreement to veterinary facilities in Fairbanks. Stress protein samples will be sent to Stanford Research Institute for analysis. All other analytical processes will be carried out by UAF personnel. Boat and direct field support will be through our ongoing collaboration with ADFG.

E. Location

Harbor seals will be captured in the EVOS event area in central and southwest PWS.

PROJECT IMPLEMENTATION/COORDINATION OF INTEGRATED RESEARCH EFFORT

As noted above, this project on the health of harbor seals, is submitted jointly as part of the Marine Mammal Ecosystems program. This component is being run by the marine mammal physiology group at UAF. Other state agencies, federal agencies and universities will be in charge of other components of the project. UAF, ADFG and NOAA currently collaborate with each other on marine mammal biology projects in and around Alaska. This project expands and builds on that collaboration and extends the depth of the project to focus on the EVOS event.

FY 95 BUDGET (\$K)

Personnel	39.3
Travel	5.1
Contractual	7.7
Commodities	3.5
Equipment	12.3
Indirect Costs	20.1
Subtotal	88.0
Gen. Admin.	6.4
Total	94.4

Diet Composition, Reproductive Energetics, and Productivity of Seabirds Damaged by the *Exxon Valdez* Oil Spill

Project Number:	95118-BAA
Restoration Category:	Research (new)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	NOAA
Cost FY 95:	\$140,600
Cost FY 96:	\$144,100
Total Cost:	Unknown
Duration:	3 years (useful results can be obtained in two years, but to be effective the project should be supported for a minimum of three years)
Geographic Area:	Prince William Sound (Naked Island, Shoup Bay, Jackpot Island, Fool Island, Icy Bay, Blackstone Bay)
Injured Resource/Service:	Multiple resources

INTRODUCTION

Three seabird species that were damaged by the *Exxon Valdez* oil spill (EVOS) are failing to recover at an acceptable rate: pigeon guillemot (*Cepphus columba*), common murre (*Uria aalge*), and marbled murrelet (*Brachyramphus marmoratus*). Damage from the spill to a fourth species of seabird, black-legged kittiwake (*Rissa tridactyla*), is equivocal, but recent reproductive failures of kittiwakes within the spill area may be due to longer term ecosystem perturbation related to the spill). The status of pigeon guillemots and marbled murrelets in Prince William Sound (PWS) and the Northern Gulf of Alaska has been of concern for nearly a decade due to declines in numbers of adults observed on survey routes.

The failure of these seabirds to recover has been attributed to low reproductive success, but there is a troubling lack of information on the factors ultimately responsible for low productivity. One prevalent hypothesis is that changes in the abundance and species composition of forage fish resources within the spill area has resulted in food provisioning rates that are below the requirements of growing nestlings. Concurrent population declines in some

marine mammals, particularly harbor seals, have also been blamed on food limitations. Whether these changes in forage fish availability are related to or have been exacerbated by EVOS is unknown.

Reproductive success in seabirds is largely dependent on foraging constraints experienced by breeding adults. Previous studies on the reproductive energetics of seabirds have indicated that productivity is energy-limited, particularly during brood-rearing. Also, the young of most seabird species accumulate substantial fat stores prior to fledging, an energy reserve that is crucial for post-fledging survival. Data on foraging habitats, prey availability, and diet composition are critical for understanding the effects of changes in the distribution and abundance of forage fish resources on the productivity and dynamics of seabird populations.

The composition of forage fish is particularly relevant to reproductive success because it is the primary determinant of the energy density of chick diets. Parent seabirds that transport chick meals in their stomachs (e.g., kittiwakes) or in a specialized pouch (e.g., auklets) normally transport meals that are close to the maximum load. Seabirds that transport chick meals as single prey items held in the bill (e.g., guillemots, murres, murrelets) experience additional constraints on meal size if optimal-sized prey are not readily available. Consequently, seabird parents that provision their young with fish high in lipids are able to support faster growing chicks that fledge earlier and with larger fat reserves. This is because the energy density of lipid is approximately twice that of protein and carbohydrate. Also, forage fish are generally very low in carbohydrate, and metabolism of protein as an energy source requires the energetically expensive process of excreting the resultant nitrogenous waste. While breeding adults can afford to consume prey that are low quality (i.e., low in lipid) but abundant, reproductive success is largely dependent on provisioning young with high quality food items. If prey of adequate quality to support normal nestling growth and development are not available, nestlings either starve in the nest or prolong the nestling period and fledge with low fat reserves.

Forage fish vary considerably in lipid content, lipid:protein ratio, energy density, and nutritional quality. Much of the energy content of prey consumed by seabirds is in the form of neutral lipids, especially triglycerides and wax esters, and wax esters in particular are known to be difficult to digest. In some seabird prey, such as lanternfishes (*Myctophidae*), lipids may constitute as much as 50% of dry mass; while in other prey, such as juvenile walleye pollack (*Theragra chalcogramma*), lipids are less than 5% of dry mass. This means that a given mass of lanternfish has more than twice the energy content of the same mass of juvenile pollack. Published values for lipid content (% dry mass) of other forage fish are intermediate between those of lanternfish and juvenile pollack: herring (*Clupeidae*) - 36.7%, sandlance (*Ammodytidae*) - 24.4%, smelt (*Osmeridae*) - 15.8%, capelin (*Mallotus villosus*) - 15.3%. These studies have shown that for a particular species of forage fish, lipid content can vary widely with season, sex, reproductive status, and age class. For example, sandlance can vary from 10% lipid (% dry mass) to 31.5% lipid and gravid female capelin have nearly twice the energy density of male capelin. By increasing the proportion of high-lipid fish in chick diets, parents can increase the energy density of chick meals in order to compensate for the low frequency of chick feeding.

NEED FOR THE PROJECT

This study is relevant to EVOS Restoration Work because it is designed to develop a better understanding of how shifts in the diet of seabirds breeding in PWS affect reproductive success. Unlike marine mammals, seabirds offer the possibility of directly measuring diet composition and feeding rates, and their relation to productivity. By monitoring the composition and provisioning rates of seabird nestling diets, prey preferences can be assessed. Measuring provisioning rates is crucial because even very poor quality prey may constitute an acceptable diet if it can be supplied at a high rate. Understanding the diet composition, foraging niche, and energetic constraints on seabirds breeding within the spill area will be crucial for designing management initiatives to enhance productivity in species that are failing to recover from EVOS. If forage fish that are high in lipids are an essential resource for successful reproduction, then efforts can be focused on assessing stocks of preferred forage fish and the factors that impinge on the availability of these resources within foraging distance of breeding colonies in PWS. As long as the significance of diet composition is not understood, it will be difficult to interpret shifts in the utilization of forage fishes and develop a management plan for effective recovery of damaged species.

There is a definite need for information on the relationship between diet and reproductive success for pigeon guillemots, common murres, and marbled murrelets, all seabird species that are failing to recover from EVOS at an acceptable rate. However, the latter two species pose serious problems for studies of diet composition in the spill area. For common murres it is difficult to collect quantitative data on diet composition, feeding rate, meal size, and chick growth rates without seriously impacting productivity because this species nests in dense colonies on narrow ledges where human activity can cause high losses of eggs and chicks. Also, murre chicks leave the nest site to go to sea at only c. 21 days post-hatch, when they are only 20% of adult mass. In addition, the murre colonies most damaged by the spill and slowest to recover are located in the Barren Islands, where few nesting ledges are accessible. Marbled murrelet nests are usually located high in mature conifers and are very difficult to locate. Most nest visits by parents provisioning young occur at night, so monitoring chick diets is highly problematic. While some limited information on chick diets may be obtained as part of on-going EVOS studies of common murres in the Barren Islands and marbled murrelets breeding on Naked Island, neither of these species are feasible study subjects for assessing the role of diet composition for seabird reproductive success in the spill area.

Guillemots are the most neritic members of the marine bird family Alcidae (i.e., murres, puffins, and auks), and like the other members of the family, capture prey during pursuit-dives. Pigeon guillemots are a well-suited species for monitoring forage fish availability for several reasons: (1) they are a common and widespread seabird species breeding in Prince William Sound; (2) they primarily forage within 5 km of the nest site; (3) unlike most seabird species, they do not breed in large, dense colonies; (4) they raise their young almost entirely on fish; (5) they prey on a wide variety of fishes, including schooling forage fish (e.g., sandlance, herring, smelt) and subtidal/nearshore bottom fish (blennies, sculpins); (6) the one- or two-chick broods are fed in the nest until the young reach adult body size. In addition, there is strong evidence that most guillemot pairs breeding at Naked Island within the spill area have specialized on

schooling forage fish during the chick-rearing period, and that these pairs fail to raise young when forage fish are not available. Guillemots carry whole fish in their bills to the nest-site crevice to feed their young. Thus individual prey items can be identified, weighed, measured, and collected for composition analyses.

Black-legged kittiwakes also breed abundantly in the spill area and rely largely on forage fish during reproduction. Unlike guillemots, kittiwakes are efficient fliers, forage at considerable distances from the nest, and capture prey at or near the surface. Although kittiwakes are highly colonial, cliff-nesting seabirds, they construct nests and can be readily studied at the breeding colony without causing substantial egg loss and chick mortality. Several breeding colonies of black-legged kittiwakes in PWS are easily accessible so that chicks can be weighed regularly without resorting to technical climbing. Diets fed to kittiwake chicks in PWS consist primarily of schooling forage fish (i.e., sandlance, herring, juvenile walleye pollock), but when forage fish are scarce, euphausiids may be substituted. Like guillemots, kittiwakes can raise one- or two-chick broods, and chicks remain in the nest until nearly adult size. Together with pigeon guillemots, black-legged kittiwakes are excellent bioindicators of the distribution and abundance of preferred forage fish in PWS.

The proposed research is the first focused study to investigate the effects of diet composition on reproductive energetics and productivity of piscivorous seabirds in PWS. The research will result in a fundamental advance in our understanding of the significance of prey composition for pigeon guillemot and black-legged kittiwake reproduction, as well as for other seabirds and marine mammals that breed in PWS. The research will also provide new information relevant to several additional areas of study: (1) comparative biochemical composition and physiological condition of forage fishes, (2) factors such as age class, sex, size, and reproductive status as they influence the nutritional quality of forage fishes, (3) responses of breeding seabirds to shifts in prey availability, and (4) the energetic consequences of foraging on different prey with differing energy content. This research will be the first to (1) measure the nutritional quality of various forage fishes used by breeding seabirds in PWS, (2) use data on diet composition and provisioning rates to construct energetics models of chick growth and survival, and (3) monitor fat deposition rates of individual seabird chicks on differing dietary regimes by repeated, noninvasive analysis. In addition, the results will have broader implications for our understanding of dietary constraints on reproductive success in other piscivorous seabirds damaged by the spill (common murre, marbled murrelet) and will enhance our understanding of the adaptive significance of prey preferences in these seabirds. These results are crucial for understanding the factors constraining recovery of marine birds and mammals damaged by the spill.

PROJECT DESIGN

A. Objectives

The overall objective of the proposed research is to determine the energy content and nutritional value of various forage fishes used by seabirds breeding in the EVOS area, and to

relate differences in prey quality and availability to reproductive success and physiological condition of breeding adults. The proposed research will emphasize pigeon guillemots and black-legged kittiwakes for practical reasons, but prey composition and quality will be evaluated for common murres, marbled murrelets, and tufted puffins as data and samples permit. Specific objectives are enumerated below:

1. To determine the nutritional quality of various forage fish species consumed by seabirds in the EVOS area as a function of size, sex, age class, and reproductive status, including:
 - a) lipid content
 - b) water content
 - c) ash-free lean dry matter (protein) content
 - d) energy density (kJ/g fresh mass)
 - e) lipid composition (triglyceride, wax ester, mono- and diglyceride, free fatty acid, phospholipid)
2. To determine dietary parameters of pigeon guillemot and black-legged kittiwake chicks in PWS, including:
 - a) provisioning rate (meal size X delivery rate)
 - b) taxonomic composition of the diet
 - c) biochemical composition of the diet
 - d) energy density of the diet
3. To determine the relationship between diet and the growth, development, and survival of seabird nestlings. Variables measured will include:
 - a) growth rates of total body mass, lean body mass, and total body fat
 - b) rates and patterns of flight feather development
 - c) fledging age and fledgling body mass and fat reserves
4. To determine the contribution of specific forage fish resources to the overall productivity of seabird breeding pairs, including:
 - a) body composition (physiological condition) of parents raising chicks
 - a) gross foraging efficiency of parents
 - b) conversion efficiency of food to biomass in chicks
 - c) net production efficiency of the parent/offspring unit

B. Methods

The proposed research approach utilizes a combination of sample/data collection in the field (in conjunction with other EVOS seabird studies in PWS) and laboratory analyses. Sample collection and field data collection will be conducted concurrently during the 1995, 1996, and 1997 breeding seasons at three guillemot and three kittiwake colonies in PWS. Thirty active and accessible nests of each species will be located and marked during early incubation at each of the study colonies during the three breeding seasons. These nests will be closely-monitored until the young fledge or the nesting attempt fails.

Fresh samples of forage fishes for proximate analysis will be collected using three techniques: (1) temporarily placing "neckties" on guillemot chicks to prevent them from swallowing prey delivered by parents and retrieving samples from chicks, (2) temporarily placing screens in the entrance of puffin nest burrows and retrieving the chick meals left by adults, and (3) collections from at sea trawls conducted as part of proposed studies of the distribution and abundance of forage fish in PWS. Kittiwakes transport chick meals in the stomach, so chick diet samples will consist of semi-digested food. Kittiwake meal samples are normally collected when chicks regurgitate during routine weighing and measuring. Fresh fish samples and kittiwake regurgitations will be weighed (± 0.1 g) in the field and immediately frozen for shipment to my laboratory at University of Alaska Fairbanks, where they will be kept in an ultra-low freezer at -70°C until proximate analysis. In the lab, forage fish specimens will be reweighed (± 0.1 mg), identified to species, aged, sexed, measured, and reproductive status (gravid, recently spawned, nonreproductive) determined. Kittiwake regurgitations will be sorted into prey classes to the extent feasible, but otherwise handled as with fresh prey samples. Forage fish specimens will be dried to constant mass in a convection oven at 60°C to determine water content. Lipid content of a subsample of dried forage fish will be determined by solvent extraction using a soxhlet apparatus and petroleum ether as the solvent system. Lean dry fish samples will then be ashed in a muffle furnace at 500°C in order to calculate ash-free lean dry mass by subtraction. A subsample of dried forage fish samples will be combusted in a bomb calorimeter to determine energy density. Energy content of chick diets will be calculated from both the energy densities determined by bomb calorimetry and the composition (water, lipid, lipid-free dry matter, and ash) of forage fish along with published energy equivalents of these fractions.

The lipid composition of forage fish (percentage wax esters, triglycerides, mono- and diglycerides, free fatty acids, and phospholipids of total lipids) will be determined by extracting total lipids from a subsample of fresh-frozen forage fish using the Bligh and Dyer technique. Extracted lipids will then be separated into the various lipid classes and quantitated using TLC/FID analysis procedures. This procedure will allow us to determine the percentage of total lipids in forage fish that are in the form of wax esters and other refractory (hard to digest) lipid classes. My laboratory is equipped with all the instrumentation required for proximate analysis of samples, including a Soxtec HT-12 soxhlet apparatus; an Iatroscan TLC/FID system; and a Parr automated adiabatic bomb calorimeter.

Chick provisioning rates for pigeon guillemots and black-legged kittiwakes in PWS will be determined by monitoring active nests to determine meal delivery rates throughout the 24 h period. Average meal size, taxonomic and biochemical composition of the diet, and average energy density of chick meals will be determined as part of analyses of diet samples collected from guillemot and kittiwake chicks.

Known-age chicks will be weighed and measured regularly to determine individual growth rates throughout the nestling period. Total body fat of chicks at 20 and 30 days post-hatch will be determined by noninvasive (nondestructive) measurement of total body electrical conductivity. Fat reserves of chicks will be measured in the field using a total body electrical conductivity (TOBEC) fat analyzer (SA-3000 Small Animal Body Composition Analyzer from EM-SCAN, Inc., Springfield, IL). The TOBEC method relies on the major difference in conductivity

between lipids and other body constituents to estimate total lean body mass). The difference between total body mass, as determined by weighing, and lean body mass, estimated by TOBEC, provides an estimate of total body lipid. A major advantage of the technique is that measurements can be obtained rapidly and repeatedly without harm to the subject. Also, validation studies to date indicate that accuracy is high ($r^2 = .996$). The SA-3000 TOBEC analyzer can be used in the field and powered from a 12 volt battery, so chicks can be measured for TOBEC and returned to their nest in a matter of minutes. Body mass, primary feather development, and total body fat measurements will be used to develop a condition index for each chick at 20 and 30 days post-hatch.

The effects of diet composition on the physiological condition of breeding adults will be monitored using a combination of direct and indirect methods. Attentiveness of adults will be monitored during the incubation period. Adults will be captured on the nest early in the chick-rearing period and body composition determined nondestructively by TOBEC analysis. Frequency of chick meal delivery and meal size will be determined during the chick-rearing period as part of diet composition studies.

Data on chick age-specific body mass, wing chord, and primary feather length will be separated by year and diet, and fit to Gompertz sigmoidal growth models. Growth constants (K), inflection points (I), and asymptotes (A) of fitted curves will be statistically analyzed for significant differences among years and diets. Lipid deposition rates from TOBEC analysis will be compared using slopes of least squares linear regression models. Gross foraging efficiency of adults will be calculated from daily energy expenditure by the following equation:

$$([M \cdot F \cdot D] + DEE) / DEE = GFE,$$

where M is average chick meal mass in grams, F is average frequency of meal delivery in meals day⁻¹ parent⁻¹, D is energy density of chick meals in kJ/gram, DEE is adult daily energy expenditure in kJ/day, and GFE is adult gross foraging efficiency in kJ consumed/kJ expended. Daily energy expenditures of pigeon guillemots, black-legged kittiwakes, and common murrelets have been measured previously using the doubly-labeled water technique and are available in the published literature. Net production efficiency of chicks as a function of age will be calculated by regressing the change in body mass over a 24 hour period against the mass of food consumed during the period, as determined by periodic weighing. Comparison of food conversion efficiency of chicks will provide an estimate of the relative energetic efficiency of diets composed of various forage fishes. The net production efficiency of the parent/offspring unit will be calculated for each diet and each year for both species using the equation:

$$CFCE / ([DEE \cdot 2] + [M \cdot F \cdot D]) = TNPE,$$

where CFCE is chick food conversion efficiency in grams of body mass gained per gram food ingested, TNPE is the total net production efficiency of the parent/offspring unit in grams gained by chicks per kJ of energy expended by both parents, and other variables are as described above.

C. Schedule

Field work in Prince William Sound will be conducted during the 1995, 1996, and 1997 breeding seasons. Data collection during three field seasons will be necessary in order to provide minimal information on interannual variation in diet composition and reproductive success. Guillemots and kittiwakes normally lay eggs from late May to late June and raise their young during July and early August. Active, accessible nests of the two study species will be located and marked early in the incubation period during late May and early June. Marked nests will be checked daily during the hatching period to determine hatching date, and chicks will be banded soon after hatching so that individual growth rates can be monitored throughout the nestling period. Samples of chick meals and measurements of chick feeding rates will be collected throughout the nestling period. Chicks will be monitored throughout the nestling period in order to determine growth rates, fledgling age and mass, and survival until fledging.

Following the field season, chick meals will be analyzed in the lab in order to determine the taxonomic and biochemical composition of guillemot and kittiwake diets and their relationship to chick growth and survival. These analyses will be completed before the next field season in order to determine the results prior to collecting additional samples from the field. A draft annual report will be prepared in April and a final report will be submitted in June.

Following the analysis of samples collected during the 1997 field season, data collected during the three field seasons will be analyzed for relationships between diet composition and reproductive success by May 1998. The results of these analyses of diet composition and its relation to productivity and chick growth will be prepared in manuscript form and submitted by the end of FY 1998.

D. Technical Support

Laboratory analyses of the biochemical composition and energy content of forage fishes will be conducted in the laboratory of the PI. No analyses will be subcontracted to other laboratories. No new laboratory equipment will need to be purchased for the proposed research with funds provided by the grant. A laboratory technician will be hired to help the PI and graduate research assistant with processing chick meals and diet samples, and with performing of routine laboratory analyses.

E. Location

The proposed field work will be conducted in PWS. PWS supports accessible breeding population of guillemots and kittiwakes that are more than adequate for the proposed research. Field work on guillemots will be conducted at breeding colonies on Naked Island, Fool Island, and Jackpot Island. Approximately 800 pigeon guillemots nest along the shores of Naked Island, as well as smaller number of marbled murrelets and tufted puffins. The Naked Island base camp would offer an ideal base for field studies on guillemots), and Naked Island supports the highest breeding densities of guillemots in PWS). Fool Island has approximately 80 guillemot nests and Jackpot Island has about 60 guillemot nests and pairs are breeding at high

densities in both sites.

Field work on kittiwakes in PWS will be conducted at breeding colonies at Shoup Bay, Icy Bay, and Blackstone Bay. Approximately 400 black-legged kittiwakes nest at the Shoup Bay colony, 1,100 at Icy Bay, and 2,000 at Blackstone Bay.

The at-sea foraging distribution of pigeon guillemots near Naked Island, Fool Island, and Jackpot Island has been the subject of previous study, as has the species composition of the diet. Kittiwake foraging distribution and reproductive success has been monitored at the Shoup Bay colony for several years. A field camp operated by the U.S. Fish and Wildlife Service is available for field workers on Naked Island and Shoup Bay and is within walking distance of colonies where adequate numbers of accessible guillemot and kittiwake nests are available.

PROJECT IMPLEMENTATION

The proposed research will be implemented by the University of Alaska Fairbanks, with assistance from and in cooperation with U.S. Fish and Wildlife Service biologists with expertise on the proposed study species in the proposed study area. The PI (Daniel D. Roby) has extensive experience with studies of the reproductive energetics of high latitude seabirds and the relationship between diet composition and productivity. The PI currently has in his laboratory the analytical equipment necessary to accomplish the proposed laboratory analyses and is familiar with the relevant analytical procedures. To the PI's knowledge, the expertise and equipment necessary for the proposed research are not available within the federal and state agencies that compose the Trustees Council. The PI will be assisted by a Graduate Research Assistant (Ph.D. candidate), Field Technician, and undergraduate field assistant who will be carefully selected from the applicant pool as qualified to participate in the proposed research.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The research described in this proposal dovetails nicely with on-going research to assess factors limiting recovery of seabird and marine mammal populations damaged by EVOS. It is also relevant to efforts toward developing seabird models as upper trophic level sentinels of changes in the availability of forage fish, such as sandlance, juvenile pollack, herring, capelin, and smelt. The proposed research approach utilizes prey composition, reproduction rates, and energetics models to help identify and quantify the present level of forage fish availability within the PWS ecosystem. This approach is necessary because evaluation of the stocks of various forage fishes is extremely complex due to temporal and spatial variability and unpredictability in the distribution of forage fish in PWS.

Studies of foraging, reproduction, and population recovery following the EVOS are on-going for pigeon guillemots, common murres, and marbled murrelets. Black-legged kittiwakes are currently being used as indicators of ecosystem function and health within PWS. This proposal

complements those studies without duplication of effort. The PI on the present proposal will work closely with Drs. David Irons, Kathy Kuletz, and David Roseneau to coordinate data collection in the field so as to minimize project cost and maximize data acquisition.

Cooperators include Dr. David Irons of the Migratory Bird Branch, U.S. Fish and Wildlife Service. Dr. Irons has had extensive experience working in the field with both guillemots and kittiwakes nesting in PWS, and is project leader for on-going studies of the reproductive success and status of these two species in PWS. Close coordination with Dr. Irons' research teams at Naked Island and Shoup Bay will be essential for the success of the proposed research. In order to understand dietary factors responsible for poor reproductive performance of seabirds in PWS, it will be important to conduct simultaneous shipboard work (hydroacoustics) to assess the distribution and abundance of forage fish at sea. That research was recently funded by the Trustees Council and will be invaluable for interpretation of data on diets collected as part of the present proposal.

FY 95 BUDGET (\$K)

Personnel	45.7
Travel	4.7
Contractual	24.6
Commodities	17.8
Equipment	0.0
Indirect Costs	39.2
Subtotal	132.0
Gen. Admin.	8.6
Total	140.6

Proximate Composition and Energetic Context of Selected Forage Fish Species in Prince William Sound

Project Number:	95120-BAA
Restoration Category:	Research (new)
Proposed By:	Physiological Ecology Research Laboratory, Marine Mammal Research Program, Texas A&M University
Lead Trustee Agency:	NOAA
Cost FY 95:	\$43,000
Cost FY 96:	\$35,000
Total Cost:	Unknown
Duration:	4 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

As a result of damage assessment studies initiated after the *T/V Exxon Valdez* struck Bligh Reef in March, 1989, it was noted that several pelagic-feeding marine mammal and sea bird species found in Prince William Sound, AK were apparently not recovering back to predisturbance population levels. This lack of recovery may be due to a number of factors, including possible food limitations. Food limitations have been suggested to be a problem for a variety of species which are found throughout the Bering Sea and Gulf of Alaska. While cause-effect relationships are difficult to demonstrate, changes in the energetic value of prey species can be quantified and these values used in the interpretation of energy availability to the impacted species. In Prince William Sound, two marine mammal species, harbor seals (*Phoca vitulina*) and sea otters (*Enhydra lutris*), and several sea bird species: common murre (*Uria aalge*), harlequin duck (*Histrionicus histrionicus*), marbled murrelet (*Brachyramphus marmoratus*), and pigeon guillemot (*Cephus Columba*) have been impacted and are not recovering. Others, such as killer whales (*Orcinus orca*), are recovering but may be indirectly inhibiting the recovery of other species if food competition is a problem.

There is increasing interest in the use of energetic models to study interactions between marine mammals or sea birds and their prey species. Often these models are based upon energy transfer between predator and prey. Although these models require information on the energy

content or proximate composition of these species, few data are available. Those data which have been published have limited application due to the inherent seasonal and annual variability in the value of the prey. The goal of this proposed research is to assess on a seasonal and annual basis, the value of the major prey species which would be of significance to the mammalian and avian predators listed above. These data will allow for the development of models which may yield reasons for the lack of recovery of these species.

NEED FOR THE PROJECT

This study will provide the background data necessary for future studies of food web dynamics and ecology of many species of fish, birds and mammals of Prince William Sound. In any long term study of foraging ecology, especially those investigating the recovery of impacted species, knowledge of prey species composition and energetic value is critical in the interpretation of consumption rates and therefore the impact of consumer species upon prey species stocks. Compositional analysis will also yield important information on the general quality of the environment by assessing the condition of important prey species.

PROJECT DESIGN

A. Objectives

The objectives of this study are to assess the seasonal and annual changes in the proximate composition of the major forage fish species in Prince William Sound. Data on the composition and energetic value of prey species for marine mammals and sea birds are very limited. Most data which are available are for commercial species which are consumed by humans. These data are further limited, in their ecological application, because they usually only analyze the edible fillets which people consume. Another major limitation in the database relates to the lack of an appreciation of the magnitude of seasonal variability which occurs. For example, herring (*Clupea harengus*) can vary from as little as 3% lipid to as much as 22% lipid seasonally. Knowing the energy content and composition of these species will allow us to further enhance our understanding of the energetic and physiological ecology of the major consumer species in the Sound.

B. Methods

Species which should be collected are listed in Table 1. Samples should be frozen immediately after collection and be representative of the size classes which are known to be consumed by the consumer species in question.

All analytical techniques are described in detail in Worthy and Lavigne (1983) and Hislop et al. (1991). Analysis will be performed on freeze-dried, ground fish and will include determinations of water content, total lipid content, total protein content, ash content and energy density. Initially, wet mass, sex and length of each individual specimen will be recorded. Specimens

would then be combined, ground and homogenized prior to freeze-drying. Water content will be determined gravimetrically by lyophilization of ground homogenized prey until constant mass has been obtained. This will be accomplished using a LabConco Lyophilizer over a period of 4-5 days. Once the samples are dried, they are finely ground using a Spex 8000 Mixer/mill. This ground material will be used in all subsequent analyses and will be available for other investigators to use for future studies.

Lipid content will be measure gravimetrically by Soxhlet extraction using petroleum ether as the solvent. Protein content will be assessed using a modified Kjeldahl analysis and ash content will be determined by ashing at 550°C for 2 h in an ashing oven. Ground lyophilized samples will be analyzed for energy content by means of a Parr adiabatic bomb calorimeter.

C. Schedule

It is suggested that sampling be conducted a minimum of two seasons per year, when maximum productivity is occurring. If samples can be opportunistically obtained on a more regular basis, then a more detailed assessment of seasonal changes can be undertaken.

D. Technical Support

Collections will be done during NMFS and ADFG cruises, charter cruises, and through the purchase of fish from local fishermen. All of the required equipment and expertise for this project are on-site at Texas A&M University - Galveston. This includes all of the specialized equipment required for the composition and energetics analysis, as well as archival capabilities for samples and the computer related software for full statistical analysis of the data.

E. Location

Collections will take place throughout Prince William Sound and surrounding waters.

PROJECT IMPLEMENTATION

This proposal is being submitted by the Physiological Ecology Research Laboratory (PERL) of the Marine Mammal Research Program (MMRP) of Texas A&M University - Galveston. The PERL is already collaborating with National Marine Fisheries Service, National Marine Mammal Laboratory, on two other projects related to the ecology of killer whales and use of stable isotope tracers in Prince William Sound. All of the data obtained in the present study will also be incorporated into the Integrative Marine Mammal Ecosystem Program.

The PERL has 20 years of combined experience in the analysis of prey species of marine mammals for their composition and energetic value. The ultimate aim of the PERL is to develop a library of prey species samples which could be made available to researchers for future analyses, as well as to make available data on long-term changes in prey species energetic values. The PERL currently is involved in similar projects in California, Texas, Florida and eastern Canada.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Collection of prey species will be undertaken by NMFS as well as other agencies operating in Prince William Sound. Additionally dedicated cruises may be required for the collection of certain species. Samples will be archived for potential future use by other investigators interested in this area.

FY 95 BUDGET (\$K)

Personnel	20.5
Travel	3.0
Contractual	0.0
Commodities	3.5
Equipment	1.0
Indirect Costs	11.9
Subtotal	39.9
Gen. Admin.	3.1
Total	43.0

Table 1

Table 1 lists forage fish species of significance in the Prince William Sound System, which are proposed to be studied for composition and energetic value in the present study. Suggested species were determined by assessing their importance to the various sea birds and marine mammals which are found in Prince William Sound. Some species are of importance only to the larger species such as killer whales (*Orcinus orca*).

Pacific herring *Clupea harengus pallasii*
 Rockfish *Sebastes* sp.
 Cutthroat trout *Salmo clarkii*
 Capelin *Mallotus villosus* -
 Rainbow smelt *Osmerus mordax*
 Sand lance *Ammodytes hexapterus*
 Eulachon *Thaleichthys pacificus*
 Pacific cod *Gadus macrocephalus*
 Walleye pollock *Theragra chalcogramma*
 Sablefish *Anoploploma fimbria*
 Pacific sandfish *Trichodon trichodon*
 Pink salmon *Onchorhynchus gorbuscha*
 Sockeye salmon *O. nerka*
 King salmon *O. tshawytscha*
 Silver salmon *O. kisutch*
 Chum salmon *O. iceta*

Stable Isotope Ratios and Fatty Acid Signatures of Selected Forage Fish Species in PWS

Project Number:	95121
Restoration Category:	Research (new)
Proposed By:	Physiological Ecology Research Laboratory Marine Mammal Research Program Texas A&M University-Galveston
Lead Trustee Agency:	NOAA
Cost FY 95:	\$48,100
Cost FY 96:	\$11,500
Total Cost:	\$59,600
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

Food web dynamics is a central topic of ecology and fisheries and wildlife management. Evaluating the flow of energy between predator and prey is an important process in marine ecosystem dynamics. Until recently, stomach content analysis of dead animals and scat analysis provided the only sources of information on the diet of marine mammals and fish. Although widely used, these techniques have several limitations in both their methodology and results. Such limitations of these techniques provide the initiative to explore alternative methods of determining diets. Although its origins are in geology and geochemistry, the use of naturally occurring carbon and nitrogen stable isotopes have recently come forth as a powerful tool to trace ecosystem dynamics and predator prey relationships.

Previous studies on marine mammals, birds, and fish using carbon and nitrogen stable isotope tracers have shown that the isotopic composition of a prey is reflected in the tissues of the predator. The trophic level of the predator is also reflected based on its diet. Trophic level refers to the number of successive transfers of energy from resource to consumer. This technique uses differences in the ratios of carbon ($^{13}\text{C}/^{12}\text{C}$) and nitrogen ($^{15}\text{N}/^{14}\text{N}$) to trace diet

through carbon and nitrogen pathways. The carbon isotope ratio $^{13}\text{C}/^{12}\text{C}$ indicates the source of the diet whereas the nitrogen isotope ratio $^{15}\text{N}/^{14}\text{N}$ reflects the trophic level of the animal.

An advantage over traditional stomach content analysis is that the ratios of the stable carbon and nitrogen isotopes reflect the actual prey items that assimilate into the predator's tissues over time, providing a more accurate indication of their dietary history. The time course of the dietary history of an animal determined using stable isotope tracers and various tissues will depend upon the turnover rates of the tissue examined. Since individual tissue turnover rates vary based on their metabolism, analyses of stable isotopes of different tissues from the predator can provide information on the relative time frame of prey consumption. This approach with various fish tissues will depend upon the growth rate of the fish species. Slow growing fish may take years for a change in the isotopic ratio to occur in a tissue, whereas the isotope ratio in a fast growing fish may show up sooner.

If the predator consumes multiple foods, isotope values can indicate, but not prove, that a certain type of food was ingested. However, isotope tracers can sometimes prove when a food item was not consumed and assimilated. Recently, an additional method has been proposed for understanding marine food webs, even determining prey items and diet of marine mammals, through the use of fatty acid signatures. In overview, fatty acids are essentially the building blocks of lipids. Organisms are able to biosynthesize and modify fatty acids, but are subjected to biochemical limitations and differences in these processes depending on the phylogenetic group or even species. Specific fatty acids cannot be synthesized by animals, noted as essential fatty acids, and therefore can only originate from the diet. Lipids from marine organisms are characterized by an exceptionally complex array of fatty acids and substantial differences in fatty acid composition exist among species and prey types, as well as within species by geographical regions. In carnivores and marine mammals, dietary fatty acids are often deposited in body tissue without modification and therefore it is possible to trace fatty acids obtained from the diet and to compare arrays in the tissues of the predator to those in the prey consumed.

In addition to fatty acid patterns, fatty acids may sometimes be used as individual tracers. For instance, a study by Hooper *et al.* (1973) indicated that jellyfish were a component of the diet of sunfish (*Mola Mola*) on the basis of a single unusual fatty acid which was initially found in leather back turtles (*Dermochelys coriacea coriacea*) whose diet is exclusively jellyfish. The combination of using stable isotope tracers and fatty acid signatures will trace food webs beyond to what is presently possible with existing methods.

However, biological markers can also have multiple sources resulting in ambiguous results. The use of stable isotopes or fatty acids may not fully decipher the diet of an animal on their own. The use of a third approach could interpret such data whose resolution is not well defined for successful analysis. This new approach in food web analysis will be the analysis of the isotopic ratio of the fatty acids themselves. This will provide a higher resolution that may differentiate isotopic ratios and fatty acid signatures that are similar. Investigations suggest that the stable isotope compositions of discrete molecular structures more accurately reflect their origin and history than either isotopic composition or structure alone. The higher cost of this analysis preclude the use on a routine basis and will be used to interpret in situation where the results

of tracers and signatures are similar.

The strength of the combination of these three methodologies will be the ability to define and identify individual stocks of prey that are being consumed by marine mammals, fish and birds. This would provide valuable data on marine mammal-fishery, bird-fishery interactions and for fisheries management of the specific fish stocks (herring, cod, salmon) that marine mammals and birds may be impacting.

Since predators are not 100% efficient in assimilating all of the biomass ingested, the energy available to the predator from prey must be determined. This will be accomplished by using bomb calorimetry and compositional analysis to determine caloric values. This project will initiate and complement a full study of fish energetics being submitted separately.

NEED FOR THE PROJECT

This study will provide the background data necessary for future studies of food web dynamics and ecology of food resources used by many species (whales, seals, birds and fish) within Prince William Sound. With increasing pressure on our natural resources, especially fisheries, new techniques of life history interpretation and science are needed. The combination of tracer techniques will greatly enhance the knowledge available on the physiological ecology of predator-prey relationships with the Sound.

PROJECT DESIGN

The objectives of this study are to provide baseline diet, energy, and trophic level data of fish species which are prey of marine mammals and birds in Prince William Sound. Knowing the stable isotope ratios, fatty acid signatures, and caloric values of prey fish will further enhance our understanding of the food web structure of Prince William Sound and provide comparative results with stomach analysis.

It is suggested that sampling be conducted a minimum of two seasons when maximum productivity is occurring. Fish species to be sampled would be those that are known prey of marine mammals, sea birds, and large fish species. These would include capelin (*Mallotus villosus*), herring (*Clupea harengus pallasii*), sand lance (*Ammodytes hexapterus*), pollock (*Pollachius virens*) surf smelt (*Hypomesus pretiosus*), squid (*Gonatopsis maldca*, *Berryteuthis magisfer*), salmon (*Oncorhynchus sp.*), as well as macrozooplankton and euphausiids. Twelve samples from each species per sampling area would be collected. Samples will be stored frozen and shipped to Texas A&M for processing and analysis. A brief synopsis of the analytical techniques follows.

Isotope Analysis:

Carbon and nitrogen occur naturally in two stable forms. Lighter forms ^{12}C and ^{14}N are more abundant than the heavier isotopes ^{13}C and ^{15}N . The common vernacular is to refer to the heavier isotope concentrations as a ratio in δ notation in part per thousand noted (ppt) as determined from:

$$\delta X = \left[\left(\frac{R_{\text{sample}}}{R_{\text{standard}}} \right) - 1 \right] \times 1,000$$

where X is ^{13}C or ^{15}N and R is the corresponding ratio $^{13}\text{C}/^{12}\text{C}$ or $^{15}\text{N}/^{14}\text{N}$. For this study, stable isotope values will be measured using a carbon-nitrogen isotope ratio gas mass spectrometer. The stable isotope value of a predator is directly related to its diet as follows:

$$\delta_{\text{tissue}} = \delta_{\text{diet}} + \Delta \delta$$

where Δ represents the isotopic fractionation factor between dietary and consumer tissue. Carbon isotope ratios are similar for marine systems typically differing between prey protein and consumer protein by +1ppt), while nitrogen isotope ratios differ between dietary protein and consumer tissue by 3-4ppt.

Fatty acid Analysis:

Tissue samples will be extracted in 2:1 Chloroform/methanol (volume/volume) with 0.01% BHT (weight/volume) by the Folch method as modified by Iverson. Fatty acid methyl esters will be prepared directly from aliquots of the chloroform extract by the addition of borontrifluoride in methanol, sealing under nitrogen, and heating at 100°C for one hour. Following transesterification, methyl esters will be extracted and purified in hexane.

Analyses of fatty acid methyl esters will be performed according to Iverson *et al.* using temperature programmed capillary gas liquid chromatography on a Perkin Elmer Autosystem II Capillary FID Chromatograph fitted with a 30m x 0.25 mm i.d. column (J&W DB-23) and linked to a computerized integration system (Turbochrom 4 software). Identifications of fatty acids and isomers will be determined from known standard mixtures (Nu Check Prep., Elysian, MN) and silver-nitrate chromatography. Fatty acids will be designated by shorthand IUPAC nomenclature of carbon chain length:number of double bonds and location (n-x) of the double bond nearest the terminal methyl group.

Fatty acid data will be analyzed using a multivariate statistic method (tree-based regression models) which has been successfully applied to the analysis of these types of data.

Stable isotope-fatty acid analysis: A gas chromatograph-isotope mass spectrometer will be used to analyze the stable isotope ratios of individual fatty acid molecules. This instrument performs stable carbon isotope analyses of individual compounds separated by gas-chromatography. This technique of using a gas chromatograph-isotope ratio mass spectrometer combines the separatory power of capillary gas chromatography with the precision of a mass spectrometer.

PROJECT IMPLEMENTATION

This proposal is being submitted by the Physiological Ecology Research Laboratory (PERL) of the Marine Mammal Research Program at Texas A&M University-Galveston. The uniqueness and strength of this proposal is the association of PERL with the stable isotope labs at Texas A&M University-College Station, and the fatty acid lab at Dalhousie University, Halifax that will be combining to analyze the samples. Data collected would be available to other agencies involved in restoration projects.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Collection of prey species will be undertaken by NMFS. Sample analysis will be multifaceted within Texas A&M University Depts. of Marine Biology, Oceanography, and Rangeland Ecology and Management and Dalhousie University, Halifax, Nova Scotia Dept. of Biology.

FY 95 BUDGET (\$K)

Personnel	17.3
Travel	4.0
Contractual	9.1
Commodities	1.5
Equipment	0.0
Subtotal	44.9
Gen. Admin.	3.2
Total	48.1

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Habitat Protection and Acquisition Support

Project Number:	95126
Restoration Category:	Habitat Protection (continuation of 94126)
Proposed By:	Habitat Work Group
Lead Trustee Agency:	ADNR
Cooperating Agencies:	ADFG, DOI, USFS
Cost FY 95:	\$1,099,500
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	Ongoing
Geographic Area:	Prince William Sound, Kenai Peninsula, Alaska Peninsula, and Kodiak Archipelago
Injured Resource/Service:	Multiple resources

INTRODUCTION

This project is designed to support habitat protection activities of the Trustee Council and is a continuation of the Comprehensive Habitat Protection Process. These activities include evaluations by the Habitat Work Group (HWG), appraisals, title searches, hazardous materials surveys and other efforts necessary for the Trustee Council to achieve habitat protection objectives. In 1993 the Restoration Team, Habitat Protection Work Group conducted a survey and assessment of selected large parcels of private land (> 1000 acres) within the oil spill zone. The lands were mapped, scored and ranked to determine the restoration value of these areas to injured resources and services and the benefits that could be achieved through habitat protection. Successful negotiations were conducted with owners of lands within Kachemak Bay State Park and on northern Afognak Island resulting in the purchase of the park inholdings and in the establishment of the Afognak Island State Park.

During 1994, technical support continues to be provided to the Executive Director, negotiators and appraisers engaged in negotiations with landowners. Parcel boundaries were refined by HWG in order to capture the key habitats within the smallest possible land area. Packages of ranked parcels, selected either by the negotiators or by HWG, as logical negotiation units, were evaluated and ranked. The results were provided to the negotiators and to the Executive

Director. Secondary evaluations were conducted on acquisition proposals wherein less than fee simple interests were negotiated. Additional large parcels were identified for site surveys, evaluation and ranking which will take place during the summer field season. Presentation materials including numerous maps were produced and used by the Executive Director and negotiators in presentations to the Trustee Council and the public.

In 1994, a method was developed for nominating, processing, evaluating and ranking parcels of private land less than 1000 acres, i.e., *The Small Parcel Process*. Responses to the solicitation for nominations of small parcels are currently being processed and evaluated.

NEED FOR THE PROJECT

The objective of habitat protection is to identify and protect essential wildlife and fisheries habitats and associated services and to prevent further environmental damage to resources injured by the *Exxon Valdez* oil spill. Nineteen resources and services injured by the spill are linked to protection of upland and nearshore habitats (See Project Design). Protection of lands containing these habitats prevents additional injury to resources and services and natural support systems while recovery is taking place. Active negotiations with landowners for packages of ranked parcels are currently taking place and anticipated to continue into the Fall. Evaluations, starting with field surveys, of large and small parcels submitted this Spring will also continue into the Fall. This project provides support for HWG to provide technical support to the negotiators and the Executive Director and to conduct these additional evaluations.

PROJECT DESIGN

A. Objectives

Habitat protection and acquisition is designed to protect lands linked to resources and services that were injured by the *Exxon Valdez* oil spill. Protection of these lands prevents additional injury to living resources and habitats, services and natural support systems while recovery is taking place. Habitat protection addresses cases where existing regulations affecting private land use are inadequate to protect essential habitats of recovering resources and services.

In situations where natural recovery is slow to occur or where direct restoration is neither technically feasible or cost effective, other measures need to be considered to mitigate injury. These may include replacement of injured resources and services with those that are equivalent. The affected injured resources and associated services are listed below. Habitat protection objectives and benefits for each of these resources and services would differ depending on the particular parcel and the options acquired, however, general objectives and benefits are outlined below.

1. Pink salmon, sockeye salmon, cutthroat trout, Dolly varden, herring: ensure maintenance of adequate water quality, riparian habitat and intertidal habitat for spawning and rearing.
2. Bald eagle: ensure maintenance of adequate nesting habitat and reduce disturbance in feeding and roosting areas.
3. Black oystercatcher: reduce disturbance to feeding and nesting sites.
4. Common murre: reduce disturbance in nearshore feeding areas and near nesting colonies.
5. Harbor seal and sea otters: reduce disturbance at haul-out sites, pupping sites, and in nearshore feeding areas.
6. Harlequin duck: ensure maintenance of adequate riparian habitat for nesting and brood rearing, and reduce disturbance to nearshore feeding, molting, and brood-rearing habitats.
7. Intertidal/subtidal biota: maintain water quality along shoreline and reduce disturbance in nearshore areas.
8. Marbled murrelet: ensure maintenance of adequate nesting habitat and reduce disturbance to nearshore feeding and broodrearing habitats.
9. River otter: ensure maintenance of adequate riparian and shoreline habitats for feeding and denning.
10. Recreation: Maintain or enhance public access for recreational opportunities, reduce disturbances that would create visual impacts.
11. Wilderness: Maintain wilderness qualities, reduce impacts to wilderness qualities.
13. Cultural resources: Maintain or reduce disturbance to cultural resource sites.
14. Subsistence: Ensure subsistence opportunities in known harvest areas.

B. Methods

The Habitat Protection and Acquisition Process is the method for acquiring lands or partial interests in lands that contain habitats linked to resources and/or services injured by the oil spill. Protection tools that will be considered for use by the Trustee Council include: fee acquisition, conservation easements, acquisition of partial interests, cooperative management agreements, and others. Following purchase, acquired parcels will be managed by the appropriate resource agency in a manner that is consistent with the restoration of the affected

resources and/or services. The Trustee Council will decide which agency will manage the land or may create a new management authority.

Funds from this project will be used to acquire full title or partial interests in lands, subject to approval by the Trustee Council, that contain habitats/sites linked to resources and services that were injured by the *Exxon Valdez* oil spill. Acquisition of lands or interests in lands will be accomplished according to accepted realty principles and practices. All acquisitions will require title evidence, appraisals of fair market value, litigation reports, hazardous substances surveys, legal review of title, and negotiations. Some acquisitions may require land surveys and additional ecological and mineral surveys.

This project provides for these services and any other additional services which may be necessary to enable the Trustee Council to close final purchase agreements for habitat protection on parcels under negotiation. These services may be secured either in house or contractually depending upon agency regulations and staffing requirements.

The HWG will provide support to negotiators by conducting secondary evaluations and providing primary evaluations for any newly identified parcels which the Trustee Council may wish to consider. Evaluation formats developed by the group will be used, taking into account existing data and data obtained by HWG in 1993 and 1994. Data gaps will be filled to the maximum extent possible and practicable. GIS work will be needed to sort, manage, and analyze data and to map resource information where appropriate and in response to negotiator requests.

Site reconnaissance visits and post-acquisition management surveys will be determined on a site specific basis. Travel will be via air and boat charters.

C. Schedule

Support for negotiations and appraisals, for both large and small parcels, is dependent upon the progress of negotiations with landowners and the needs of the negotiators. Negotiations are currently taking place with large parcel landowners. Evaluation and ranking of small parcels will occur during this summer and fall. It is anticipated that negotiations for small parcels will commence in January, 1995. Field surveys of recently nominated large parcels will occur this summer.

D. Technical Support

The Habitat Work Group will provide technical support to agencies during their negotiations for large and small parcels. Alaska Department of Natural Resources and the appropriate federal agencies will provide support for title searches, appraisals, and hazardous substances surveys. Maps will be produced by HWG staff and by ADNR/LRIS.

E. Location

The analysis will cover all selected lands within the oil spill zone. Lands are located within Prince William Sound, Kenai Peninsula, Kodiak/Afognak Archipelago and on the Alaska Peninsula.

PROJECT IMPLEMENTATION

The proposed project is a continuation of 94126, habitat protection projects that were started in 1992 by the Restoration Planning Work Group and outlined in concept in Volume I of the *Restoration Framework*. Implementation of this project would be by the negotiating agencies and the Habitat Work Group. This group includes four members representing ADNR, USFS, ADFG and USFWS. The HWG includes three individuals who have been working on the spill since early 1989 and who participated in the genesis and development of habitat protection as a restoration strategy. All four members are authors of the *Comprehensive Habitat Protection Process* report and participated in the development of the *Small Parcel Process*.

The multicriteria evaluation methods used in *Imminent Threat Process*, the *Large Parcel Element* and the *Small Parcel Element* of the *Comprehensive Habitat Protection Process* utilize explicit subjective values and judgments made by a group of biologists/resource managers. This collective best professional judgment can vary as a function of the subjective weights applied by different individuals. Consequently, in order to maintain a consistent collective bias in these continuing evaluations, the same team should continue the effort.

It is appropriate that ADNR continue their technical support for mapping and GIS because of their demonstrated expertise, familiarity with the project and project participants and the in-house collection of relevant digital databases.

COORDINATION OF INTEGRATED RESEARCH EFFORT

All habitat protection efforts including this project are dependent upon the results of on-going research and monitoring projects. For example, the Large Parcel Element used information from the anadromous fish stream catalog, colonial seabird catalog, bald eagle nesting maps, and data from Trustee Council funded studies on black oystercatchers, marbled murrelets and pigeon guillemots.

FY 95 BUDGET (\$K)

Personnel	363.5
Travel	51.8
Contractual	572.1
Commodities	16.2
Equipment	3.0
Subtotal	1006.6
Gen. Admin.	92.9
Total	1099.5

Nanwalek/Port Graham/Tatitlek Clam Restoration Project

Project Number:	95131
Restoration Category:	General Restoration (new)
Proposed By:	Nanwalek and Port Graham Village Councils
Lead Trustee Agency:	ADFG
Cost FY 95:	\$445,000
Cost FY 96:	\$528,600
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Port Graham/Nanwalek and Tatitlek areas
Injured Resource/Service:	Subsistence and clams

INTRODUCTION

This project will develop the technology to and begin to reestablish local clam populations for subsistence use in the Nanwalek/Port Graham area and in the Tatitlek area. Clams were once a major subsistence food in these communities, but the local clam populations have decreased to very low levels in recent years and their contribution to the subsistence harvest has been greatly reduced.

There are probably several reasons why local clam populations are currently at low levels. These include changes in current patterns and beach configurations resulting from the 1964 earthquake, increasingly heavy sea otter predation and the *Exxon Valdez* oil spill.

The oil spill impacted the wild clam populations and their importance as a subsistence food in two ways. First, many clam beds suffered from direct oiling. The impact of the oil on the clam beds in Windy Bay, for instance, destroyed one of the most productive clam beds in the lower Kenai Peninsula. Second, even though some shellfish weren't killed from the oil, they have a tendency to accumulate, concentrate and store the toxic contaminants from non-lethal amounts of oil. This has badly eroded the confidence in the villages in the healthfulness of the remaining wild clam populations as a subsistence food.

One of the main problems with clam enhancement in Alaska has been the availability of a sufficient supply of seedstock. The Qutekcak Native Tribe of Seward is developing a shellfish hatchery that is currently focusing on providing Pacific oyster seed for the Alaskan aquatic farming industry. The hatchery has also been working to develop the technology for producing clam seedstock and is currently working on the Littleneck clam. This clam has never before been produced in a hatchery. However, the hatchery staff has been able to bring small batches of Littleneck clams through the most critical stage of development and it seems certain that the techniques for successfully producing Littleneck clam seedstock in the hatchery can be developed. In addition to Littleneck clams the hatchery will soon will doing seedstock development work on Butter clams. A major part of this project will be enabling the Qutekcak hatchery to provide the needed quantities of seedstock for developing populations of clams near the Native villages.

NEED FOR THE PROJECT

This project will provide the villages of Nanwalek, Port Graham and Tatitlek with an easily accessible source of clams for subsistence use. These clams will also be afforded some measure of protection against sea otter predation. With the wild clam populations at a low ebb, the questionable safety as a food source of those that remain in addition to the heavy sea otter predation that these clams are now subjected to, the need to develop safe, protected sources of clams for the villages is greater than ever. If this project is successful it will enable the villages to develop their own supplies of this traditional subsistence food.

PROJECT DESIGN

A. Objectives

1. Develop the techniques and the capacity in the Qutekcak hatchery for producing sufficient quantities of various sized clam seed.
2. Obtain the required permits for conducting the field work
3. Determine the survival and duration of culture to harvest size for different sizes of seed.
4. Determine the growth rates and survival in different types of substrate.
5. Determine the efficacy of various types of passive predator control measures such as fabric covers, bird netting and rack and bag culture.

B. Schedule

The hatchery work will run year round. The field season for testing the various culture scenarios will run from late April to the end of October. Reports will be done quarterly with the annual report issued in January.

C. Technical Support

Technical assistance will be needed in the hatchery operations, in setting up field trials and in testing clams for contamination.

D. Location

The Qutekcak shellfish hatchery is in Seward. Field work will take place in the Port Graham/Nanwalek area and in the Tatitlek area.

PROJECT IMPLEMENTATION

This project will be implemented by project teams selected and controlled by the village councils.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Technical assistance and services will be obtained from private contractors, the Chugach Regional Resources Commission (CRRC), the Alaska Department of Fish & Game (ADFG), the Alaska Department of Natural Resources (DNR) and the Alaska Department of Environmental Conservation (DEC).

FY 95 BUDGET (\$K)

Personnel	7.2
Travel	0.0
Contractual	415.9
Commodities	0.0
Equipment	0.0
Subtotal	423.1
Gen. Admin.	21.9
Total	445.0

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Port Graham and Nanwalek Subsistence Baseline

Project Number:	95132
Restoration Category:	General Restoration (new)
Proposed By:	Port Graham and Nanwalek Village Councils
Lead Trustee Agency:	ADFG
Cost FY 95:	\$518,700
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	2 years
Geographic Area:	Lower Kenai Peninsula from Port Graham Bay to Port Dick
Injured Resource/Service:	Subsistence

INTRODUCTION

This project proposes a subsistence foods testing program to establish baseline data on all subsistence salmon fishing and shellfish gathering areas used by the people of Port Graham and Nanwalek.

NEED FOR THE PROJECT

Many of the areas used by residents of Port Graham and Nanwalek were impacted by oil as a result of the *Exxon Valdez* oil spill. Even now (summer 1994), tarballs continue to wash up on these harvest areas. The continued presence of oil has caused residents of these communities to be wary of using resources, especially shellfish, from their traditional harvest areas. While some samples of subsistence foods from the harvest areas of Port Graham and Nanwalek have been tested for the presence of hydrocarbons under studies conducted by the Oil Spill Health Task Force, the Division of Subsistence of the Alaska Department of Fish and Game, the National Oceanic and Atmospheric Administration, and Exxon, funds were limited and only a few sites or species could be tested. Residents of these communities want a more comprehensive survey and testing of resources from their harvest areas.

This project would give the people of Port Graham and Nanwalek very specific information on what subsistence foods are safe to eat, and the location of subsistence foods that continue to be contaminated. It would also provide information that can be used as a baseline for comparison in the event of another oil spill reaching these areas.

PROJECT DESIGN

A. Objectives

To provide very specific, detailed, and comprehensive information to the residents of Port Graham and Nanwalek on the safety of subsistence resources in their traditional harvest areas. A second, subsidiary goal is to establish a baseline of hydrocarbon exposure for comparison in the event of another oil spill.

B. Methods

Samples of clams, chitons, snails, mussels, cockles, whelks, octopus and all species of salmon will be collected, where they occur, in ten bays from Port Graham Bay to Port Dick on the lower Kenai Peninsula. Three locations will be tested in each bay. Four samples of each shellfish species to be tested should be collected at each location. Eight individuals of each species of salmon to be tested should be sampled at each location. Bile and flesh samples will be taken from each salmon, to allow for bile metabolite screening.

A biological consultant will be contracted to oversee the collection of samples. The biological consultant will provide sampling supplies. Trained field assistants are locally available in each community. There will also be a local project leader who will supervise local hiring, monitor the performance of the biological consultant, and communicate results of the testing back to the communities.

The samples will be tested for hydrocarbon contamination. In order to provide consistency with earlier testing, the samples should ideally be tested at the National Marine Fisheries Service laboratory in Seattle.

C. Schedule

Samples will be collected during low tide cycles throughout the spring of 1995 and 1996.

D. Technical Support

It will be necessary to contract with a biological consultant to oversee the collection of samples and apply for the necessary scientific collection permits. The services of a biological laboratory specializing in hydrocarbon bioassay will also be required. Ideally, the samples should be tested at the NMFS laboratory in Seattle, to provide consistency with earlier studies. Additional technical support in setting up the project may be provided by the Alaska Department of Fish

and Game, Division of Subsistence. The Oil Spill Health Task Force and the Expert Toxicological Committee may provide assistance in the interpretation of test results.

E. Location

The project will be conducted on the lower Kenai Peninsula from Port Graham Bay to Port Dick, including the communities of Port Graham and Nanwalek. Testing of samples may be carried out in Seattle.

PROJECT IMPLEMENTATION

The project should be implemented by the Village Councils of Port Graham and Nanwalek.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is part of the Subsistence Restoration Planning and Implementation Project (94428), and would further the goal of restoring subsistence services damaged by the EVOS. It would carry on work done under the Subsistence Foods Testing Project (93017 and 94279), to help restore the confidence of subsistence users in their ability to determine the safety of their traditional wild foods. The project would also help to establish a baseline of hydrocarbon exposure of shellfish and salmon in this area for comparison in the event of another oil spill.

FY 95 BUDGET (\$K)

Personnel	7.2
Travel	0.0
Contractual	488.2
Commodities	0.0
Equipment	0.0
Subtotal	495.4
Gen. Admin.	23.3
Total	518.7

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English Bay River Sockeye Salmon Subsistence Project

Project Number:	95133
Restoration Category:	General Restoration (new)
Proposed By:	Nanwalek Traditional Council
Lead Agency:	ADFG
Cost FY 95:	\$147,200
Cost FY 96:	\$143,100
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	English Bay Lake system
Injured Resource/Service:	Sockeye salmon and subsistence

INTRODUCTION

This project will assist in the effort to build the English Bay sockeye salmon run back to historic levels. The sockeye salmon return to the English Bay River near the villages of Nanwalek and Port Graham was once a primary source of subsistence and cash for the villagers. Over the past 12 years or so the returns have dropped steadily from the 30,000 range to the current 5,000 range. This has resulted in a complete closure of both the subsistence and the commercial fishery.

The EVOS clean-up effort had a negative impact on the English Bay sockeye. Boom deployment during the early phases of the clean-up trapped a large number of outmigrating sockeye smolt in the boom curtain on the ebbing tides causing high levels of mortality. This, plus the loss of other subsistence resources in the area by the spill and the basic health concern that the villagers have with eating fish and marine plants from the spill area, has put emphasis on the need to build the English Bay sockeye return back up to a level that will support heavy subsistence use and a revived commercial fishery.

Studies were undertaken in 1990 by the Chugach Regional Resources Commission (CRRRC) in cooperation with ADFG to determine the best approach to increasing the English Bay sockeye return. It was determined that smolt production in the system was the bottleneck to increasing the returns. A smolt production pilot project was initiated in 1991 employing lake pen rearing techniques to rear English Bay sockeye fry produced in a hatchery to presmolt in net pens and releasing into the system in the late fall for outmigration the following spring. The program proved successful and has been upgraded and expanded.

The program is proving to be a cost effective method of increasing the return to the English Bay River system. It is designed to be self-sustaining beyond the development stage. If successful over the long run it will provide a safe, reliable and badly needed supply of salmon to meet the area's subsistence and economic needs. However, additional funds are needed to sustain this enhancement effort. Additional funding is being requested under this project to ensure that the total program will continue through the development stage.

NEED FOR THE PROJECT

This project will provide the villages of Nanwalek and Port Graham with the means to increase the local sockeye run. In the past this run has been a vital part of the economic and social fabric of these communities. With the safety and availability of other fisheries resources in the area in doubt, the need to restore and enhance this sockeye run is more important than ever. This resource has the potential of providing these villages with a safe and reliable supply of a traditional subsistence food.

PROJECT DESIGN

A. Objectives

1. In 1995, 1996 and 1997 take 1.2 million English Bay sockeye eggs each year for incubation at the Port Graham Hatchery.
2. Transfer the resultant fry from the Port Graham hatchery to net pens in the English Bay lakes for rearing to at least eight grams and release into the system just before freeze-up.
3. Count the number of smolt leaving the system each year and the number of adults entering it. Collect pertinent information from any tagged fish.
4. Do an acoustic survey of the English Bay system, after the annual smolt outmigration is over, to determine the biomass of hold-over smolt.

C. Schedule

The field season runs from April to the end of November each year. The smolt out-migration takes place from early May through June; the pen rearing operation runs from early June to just before freeze-up; the eggtake occurs in August and the acoustical survey is done in late July. Reports are done quarterly with the annual report issued in January.

D. Technical Support

Technical assistance is needed in fish culture, tags analysis and the acoustical surveys.

E. Location

The English Bay Lake system.

PROJECT IMPLEMENTATION

This project will be implemented by the Nanwalek Sockeye Development Team, an arm of the Nanwalek Traditional Council.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Technical assistance and services are being provided by the Chugach Regional Resources Commission (CRRC) and the Alaska Department of Fish & Game (ADFG).

FY 95 BUDGET (\$K)

Personnel	7.2
Travel	0.0
Contractual	129.8
Commodities	0.0
Equipment	0.0
Subtotal	137.0
Gen. Admin.	10.2
Total	147.2

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Prince William Sound Salmon Stock Identification and Monitoring Studies

Project Number:	95137
Restoration Category:	General Restoration (continuation of 94137)
Proposed By:	ADFG
Cost FY 95:	\$277,500 (includes \$55,800 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$278,200
Total Cost:	\$555,700
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sockeye salmon and commercial fishing

INTRODUCTION

Recent annual production of wild salmon in Prince William Sound (PWS) has included from 800 to 900 thousand chum salmon (*Oncorhynchus keta*) and 300 to 500 thousand sockeye salmon (*Oncorhynchus nerka*). As with pink salmon, up to 75% of wild chum salmon spawn in intertidal areas. Oil from the *Exxon Valdez* Oil Spill (EVOS) was deposited in intertidal spawning areas for pink and chum salmon. Injuries from this contamination are well documented for pink salmon in PWS including direct lethal effects on embryos in the gravel and chronic reproductive impairment in subsequent generations exposed to oil. In addition, emergent fry and smolt of all salmon species from throughout PWS migrated through and reared in areas contaminated by oil. Willette and Carpenter (1993) demonstrated reduced growth and survival for pink salmon which reared in oiled portions of the Sound in 1989.

Chum salmon and sockeye salmon have life history similarities to pink salmon which may have also made them susceptible to injury from the EVOS. Chum salmon have both embryonic and early marine life history similarities and occur in many of the same streams as pink salmon. Sockeye salmon do not share intertidal natal habitat with pink salmon but they do spend portions of their early marine life history in areas of the Sound which were oiled. Given that both chum and sockeye salmon coexist with pink salmon during portions of the life history when EVOS related injuries occurred in the latter, it seems likely that sockeye and chum salmon were similarly injured.

Salmon stocks impacted by the EVOS are heavily exploited in commercial, sport, and subsistence fisheries. Many of these populations have been depressed in recent years and some, such as the Coghill Lake sockeye salmon population, are the subject of extensive EVOS Trustee Council restoration efforts. These restoration efforts are presently targeted at improving the productivity of the lake nursery area for juvenile sockeye salmon and cannot succeed without simultaneous efforts to improve management of the commercial fishery. The damaged populations exist in fisheries dominated by hatchery populations. The management of this mixed stock fishery has historically been based on maintaining good temporal and spatial distribution of spawning escapement for groups of wild populations (stocks) originating from eight major fishing districts and its success has relied upon the manager's ability to control stock specific exploitation rates. Restoration premised on such a management strategy will require accurate in-season catch stock composition estimates if lower harvest rates are to be achieved for damaged wild stocks.

The foundations for this project were firmly established in feasibility studies which were conducted beginning in 1986 and extending through 1988. During the damage assessment process large scale tagging and recovery projects were instituted and perfected by Natural Resources Damage Assessment (NRDA) Fish/Shellfish (F/S) Study #3. Damage assessment funds were expended for tagging hatchery releases of sockeye, coho and chinook salmon in 1989 and 1990 and releases of chum salmon in 1990. Tag recovery efforts for wild and hatchery salmon were funded by damage assessment funds in 1989, 1990, and 1991 and by restoration funds in 1993.

NEED FOR THE PROJECT

Although the extent of EVOS related injury to populations of sockeye and chum salmon in PWS is unknown, populations of wild pink salmon in PWS injured by the EVOS continue to experience poor reproductive success. Because they have life history similarities and overlap geographically with pink salmon it is likely that populations of chum and sockeye salmon were similarly injured. Populations of wild chum salmon in the northern portions of PWS are in serious decline as is the population of sockeye salmon in Coghill Lake in northern PWS. These populations must be protected from other sources of injury or mortality which could further jeopardize their ability to reproduce in adequate numbers for long term sustained yield.

Adult returns from injured wild populations mingle with other wild and hatchery populations in PWS waters and all are heavily exploited by commercial fisheries. Successful restoration of injured populations will require that they be exploited at a lower rate in these fisheries until their reproductive rates return to historic average levels. Minimizing the exploitation of injured wild populations will insure that sufficient numbers of adults enter streams to spawn for sustained yield. This project provides fisheries managers with real time estimates of the numbers of wild and hatchery fish in commercial harvests. These estimates enable managers to identify areas where exploitation of wild populations can be minimized while permitting the timely harvest of economically important hatchery returns.

PROJECT DESIGN

This project is designed to provide estimates of hatchery and wild fish contributions to commercial and cost recovery fisheries in Prince William Sound. These estimates will allow fisheries managers to monitor the size and health of wild salmon populations and lessen interceptions of wild fish in mixed stock fisheries. The project will be administered and supervised by the Alaska Department of Fish and Game.

A. Objectives

1. Make inseason estimates of the temporal and spatial contributions of tagged hatchery stocks of sockeye, chum, chinook and coho salmon to PWS commercial and hatchery harvests based on the number of tags detected in adipose clipped fish which are recovered during catch sampling;
2. Provide timely inseason estimates of hatchery and wild stock contributions to harvests by time and area to fisheries managers so they can closely regulate exploitation of injured wild stocks;
3. Use data from fully decoded tags recovered from commercial catches, cost recovery harvests, and hatchery brood stock to verify or adjust inseason contribution estimates and;
4. Estimate marine survival rates for each uniquely coded hatchery release group where possible.

B. Methods

Tag recoveries will be made from a stratified random sample. Fisheries will be stratified by district, discrete time segments and processor. For each stratum, 25% of the sockeye, chum, chinook and coho salmon commercial harvest and cost recovery harvest will be scanned for fish with a missing adipose fin. Catch sampling will be conducted in processing plants located in Cordova, Valdez, Anchorage and Whittier. Broodstock sampling will also occur at three PWS hatcheries. A minimum of 50% of the daily broodstock requirements at each hatchery will be scanned for fish with missing adipose fins.

In the catch, cost recovery and broodstock samples, the total number of fish scanned and the total number of fish with missing adipose fins will be recorded. The heads of fish with missing adipose fins will be removed, labelled and shipped to the Tag Lab in Juneau for tag removal and decoding. Tag recovery, scanning, and catch data will be merged in a computer data base and returned to Cordova for analysis.

C. Schedule

May 15 - Sept 30, 1995	Tag recoveries in commercial fisheries, cost recovery harvests, and brood stocks. Inseason catch stock composition estimates by time and area for management of commercial and cost recovery fisheries.
November 30, 1995	Draft summary report
January 15, 1996	Final Report

D. Technical Support

ADFG will supply biometrics support to ensure that project methods and data analyses will provide inseason stock contribution estimates at levels of accuracy and precision required for management of wild stocks in PWS.

E. Location

Sampling of salmon catches from commercial and cost recovery fisheries will occur in shore based processing plants in Cordova, Valdez, Whittier, and Anchorage. There will also be sampling in Seward, Kenai, and aboard floating processors if significant numbers of Prince William Sound salmon are processed at those locations. Extraction and decoding of tags will be accomplished by the ADFG coded wire tag lab in Juneau. All data analyses will be completed in Cordova with assistance from Anchorage based Alaska Department of Fish and Game biometrics staff.

PROJECT IMPLEMENTATION

This project is applied research which has direct and immediate applications to ADFG's statutory obligation to manage fisheries. Feasibility studies for the massive coded wire tagging and recovery operations required to manage PWS pink salmon were conducted by ADFG and the local, private aquaculture associations for two years prior to the EVOS. Concurrently, these agencies developed the methods described for the other species in this project, they have the infra-structure (e.g. the ADFG coded wire tag laboratory) in place for large scale tagging and tag recovery operations, and they are the logical choice for conducting this project.

The project is proposed as a cooperative effort to be funded by the Trustee Council, ADFG, and PWS aquaculture associations. Prince William Sound Aquaculture Corporation (PWSAC) and Valdez Fisheries Development Association (VFDA) spend approximately \$50K annually to apply tags to sockeye and chum salmon. ADFG provides tagging equipment and technical expertise for tagging quality control. The Trustee Council will provide the funds for tag recovery in the commercial and cost recovery fisheries and in the hatchery brood stocks.

Overall project design, supervision, coordination, data analyses, and reporting will be the responsibility of Principal Investigator Sam Sharr, the ADFG Fisheries Biologist III Salmon Research Project Leader in Prince William Sound. Carol Peckham, an ADFG Salmon Research Biologist II in Cordova will act as the Project Leader, will supervise all the day to day project activities, complete inseason analyses for the ADFG Fisheries Biologist III Area Management Biologist and, take the lead on all post season analyses and reporting. The Principal Investigator and the Project Leader will receive approval of project design and quality control procedures, review of all data analyses, and editorial support for project reports from an ADFG Biometrician I based in the ADFG Anchorage Regional Office. The ADFG Principal Investigator together with the local and regional ADFG management staff are responsible for integration of information from this project into their inseason fisheries management decisions.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The monitoring, research and restoration objectives of this project are integral to the success of ecosystem research and restoration efforts described in the Sound Ecosystem Assessment (SEA) plan. It is an integral part of a package of proposed projects including the SEA (95320), the Salmon Otolith Marking (95320C), and the Pink Salmon Egg and Alevin Mortality (95191) projects. This project monitors the total returns and survival rates of wild salmon populations which are known to be in decline and that may have experienced oil related injury similar to that demonstrated for pink salmon. Information from this project will be critical to the maintenance and restoration of populations which are exploited directly and indirectly in mixed stock salmon fisheries. This project provides survival estimates for individual release groups from PWS hatcheries. These estimates are critical to several components of SEA including those investigating:

1. The dependence of salmon survival on sea surface temperature and other oceanographic features of PWS during the fry and juvenile life stages.
2. The dependence of salmon survival on abundance, size, growth rate, and distribution of fry and juveniles and, zooplankton population distribution, abundance, and species composition.
3. The dependence of salmon survival on abundance, size, growth rate, and distribution of fry and juveniles and the abundance distribution, size, and species composition of predator populations.

This project is also directly linked to the proposed Otolith Marking project. Otolith marking is a logical extension of marking technology which will ultimately replace many of the functions of coded wire tags and provide more accurate and precise estimates of hatchery and wild contributions to salmon catches and escapements in PWS at less expense. However, until otolith marks can be applied, coded wire tagging and recovery projects will continue to provide those estimates.

This project will integrate tender fleet tracking, processor plant logistics, and crew scheduling with existing ADFG salmon port sampling projects. Local aquaculture associations which apply tags provide all tagging, fry release, sales harvest, and brood stock data necessary for data analysis. Aquaculture associations also provide room, board, and logistics support for brood stock samplers at their hatcheries. Air charter and boat transportation required to get samplers to remote locations in PWS will be shared with other projects having similar needs.

FY 95 BUDGET (\$K)

Personnel	208.8
Travel	8.6
Contractual	20.4
Commodities	7.0
Equipment	0.0
Subtotal	244.8
Gen. Admin.	32.7
Total	277.5

Elders/Youth Conference on Subsistence and the Oil Spill

Project Number:	95138
Restoration Category:	General Restoration (new)
Proposed By:	ADFG
Cost FY 95:	\$85,800
Cost FY 96:	\$0
Total Cost:	\$85,800
Duration:	1 year
Geographic Area:	Prince William Sound, Lower Cook Inlet, Kodiak Island Borough, Alaska Peninsula
Injured Resource/Service:	Subsistence

INTRODUCTION

The goal of this project is to promote the recovery of subsistence uses of natural resources of the oil spill area through a conference that would involve elders, youth, and other representatives of spill area communities. Conference goals would focus on identifying the common experiences of communities and the subsistence skills which have been affected and need to be strengthened. The role of traditional knowledge in informing people about the spill's effects would be explored. An additional goal would be to discuss experiences with past crises and identify ways to prepare for the future. Through a contract, a facilitator would be responsible for organizing the conference, including designing an agenda and a structure for the conference. The conference would be videotaped. Conference proceedings would be published and a video produced. Both of these products would serve as educational tools to further the recovery of subsistence uses through the reintegration of subsistence uses, knowledge, and values into community life.

NEED FOR THE PROJECT

Subsistence uses of natural resources are essential to the economies and ways of life of communities of the oil spill area. After the spill, these uses were severely disrupted due to natural resource injuries and concerns about the safety of using subsistence foods that may have been contaminated by oil. Because of these reduced subsistence uses, opportunities to teach subsistence skills and traditional knowledge have also been diminished. As noted in the draft

Oil Spill Restoration Plan, "the more time users spend away from subsistence activities, the less likely they will return to it" (p 32). The restoration strategy for subsistence, as presented in the draft plan (pp. 32-33), has four parts, including an objective "to accelerate recovery of subsistence resources and services." One means to achieve this goal is "through increasing availability, reliability, or quality of subsistence resources, or increasing the confidence of subsistence users."

Increasing the confidence of subsistence users may be achieved by a gathering of knowledgeable individuals (including elders) and young people in order to identify the issues and problems raised by the spill and the means to address these issues. The conference would draw upon traditional knowledge and the experience of community residents in facing past crises. It could result in a list of subsistence skills that need re-invigorating in light of the disruptions since the oil spill. Another goal would be to share observations about natural resources in the spill area and recommend activities that could assist people in understanding the present conditions of these resources. Also, the conference could identify ways for communities to use their collective traditional knowledge and experiences to prepare for future environmental disasters. There has been no similar opportunity for the communities of the spill area which depend upon the natural resources for subsistence to discuss their common experiences, concerns, and plans as proposed for this conference.

The Draft *Exxon Valdez* Oil Spill Restoration Plan (p. 33) states that, regarding subsistence, "one indication that recovery has occurred is when the cultural values provided by gathering, preparing, and sharing food are reintegrated into community life" (p. 33). The conference will contribute to this goal through the discussion and dissemination of traditional knowledge about subsistence uses and about the common experiences shared by subsistence users since the spill. Additionally, this project will assist with the restoration of subsistence through monitoring of the recovery of subsistence uses. The information discussed at the conference will provide a picture of the present status of subsistence, which may in turn be used to direct future restoration actions.

PROJECT DESIGN

A. Objectives

Objectives include a conference with participation by representatives of communities of the oil spill area, written conference proceedings, and a video.

B. Methods

A professional services contract will be awarded to design the conference agenda and serve as the conference moderator. The contractor will consult with spill area communities as appropriate to set the agenda. The contractor will also be responsible for preparing the conference proceedings. A separate contract will be awarded to video tape the conference and produce a video presentation of the conference (see below).

Among the potential topics for discussion are:

1. What has been the common experience of subsistence users of spill-area communities since the oil spill? What has been lost? What has been gained? Are there differences between regions?
2. What actions need to be taken by communities to re-invigorate subsistence uses?
3. Are there subsistence skills which need to be emphasized? How can this be accomplished?
4. Is there traditional knowledge available to inform subsistence users about the spill's effects on natural resources and the safety of subsistence foods?
5. How have people of the spill area dealt with disasters in the past? What can we learn from those experiences?
6. Given what we have learned, how can communities prepare for the possibility of future disasters and threats to subsistence?

The conference will be video-taped and audio-taped. A proceedings volume will be prepared. A one to two hour video will also be produced to present the conference highlights and recommendations. It is intended that the proceedings and video be used as educational tools to promote an exchange of information and to strengthen subsistence traditions that have been weakened since the spill.

The conference would last one or two days. Each community of the spill area (approximately 20 communities) would nominate one elder, two students (high school or college aged), and one additional representative. The exact format for the conference would need to be determined by the contractor after consultation with the communities. It would likely entail several formats, including but not limited to formal presentations, panel discussions, round tables, and question/answer periods.

C. Schedule

October 1, 1994	Project approval
October 1994	Develop contract guidelines, evaluate bids, award contract
November - January 1995	Conference planning
February 1995	Conference
March - June	Production of conference proceedings and videos
July - August	Distribution of materials
September 1995	Complete project final report

D. Technical Support

None required

E. Location

The proposed conference will take place in Anchorage, primarily because of its centralized location. If feasible in terms of cost and facilities, an alternative location can be considered.

PROJECT IMPLEMENTATION

The Division of Subsistence of the Alaska Department of Fish and Game could coordinate the implementation of this project. This would entail preparing contract proposals for competitive bids, evaluating proposals, and monitoring the performance of the contractors. The division would also handle the logistics of the conference, including meeting facilities and participants' travel and accommodations. An alternative is to contract these coordination functions to a regional organization or coalition of communities with appropriate administrative resources. In either case, professional services contracts (or subcontracts) would be awarded to design the conference, prepare the proceedings, video tape the conference, and produce an informational video which summarizes the conference findings.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Information about the status of injured natural resources can be integrated into the conference. Conference findings, including observations by subsistence harvesters of natural resource populations, will be available for use by other researchers. Other proposed subsistence restoration projects also have public information components that will benefit from the information which is shared through the conference and its resultant products.

FY 95 BUDGET (\$K)

Personnel	16.3
Travel	44.4
Contractual	21.0
Commodities	0.2
Equipment	0.0
Subtotal	81.9
Gen. Admin.	3.9
Total	85.8

Proposed Spawning Channel Port Dick Creek, Lower Cook Inlet

Project Number:	95139A
Restoration Category:	General Restoration (continuation of 94139)
Proposed By:	ADFG
Cost FY 95:	\$33,200
Cost FY 96:	\$144,500
Total Cost:	Unknown
Duration:	4 years
Geographic Area:	West Arm Port Dick, Southern Kenai Peninsula, Lower Cook Inlet
Injured Resource/Service:	Pink salmon and commercial fishing

INTRODUCTION

This project will construct a pink and chum salmon spawning channel at Port Dick Creek to accelerate and restore the salmon stocks and services lost to the local commercial salmon seine fleet. This project is a proposed continuation of two prior years pre-construction investigations.

NEED FOR THE PROJECT

To accelerate the recovery of the currently depressed wild pink and chum salmon stocks of Port Dick Creek by increasing the area available to salmon spawners.

PROJECT DESIGN

A. Objectives

The major goal of this project is the final engineering analysis during the fall of 1994 and actual

construction of the spawning channel during the summer of 1995. The objectives and completion dates are proposed as follows:

1. Continue ground water level measurements, data analysis, final engineering design and bid preparation during the winter of 1994/95.
2. Construct the spawning channel during the spring/summer of 1995.
3. Conduct stream side egg-takes with native salmon stocks and replant the eggs into the new spawning channel at the eyed stage in 1995.
4. Monitor subsequent egg/fry survival through on site evaluations beginning in the spring of 1996 through 1998.
5. Monitor adult spawner density and species composition beginning in the summer of 1998 through 1989.

B. Methods

Continued ground water level measurements will be conducted using subsurface standpipes and a battery operated stream stage recorder. Results from these measurements will be used to finalize the size, depth and actual configuration of the spawning channel. The final spawning channel design will be prepared by a qualified engineer. The design will be advertised through the official state construction bid process.

The actual construction project will be awarded to the lowest qualified bidder. Construction of the spawning channel will be conducted with appropriate heavy equipment such as D9 Caterpillar tractors. Only on-site gravel materials will be used. Mobilization and demobilization of heavy equipment and logistical support materials will be conducted using a 110 ft. landing craft vessel.

Standard fish culture methods will be used to conduct on-site Port Dick Creek chum salmon egg-takes. Instream incubation systems will be used for incubation to the eyed egg stage. Eyed egg planting devices will be used to seed the spawning channel during the first few years to increase the probability of success. Several sample plots or enclosures will be identified for subsequent evaluation.

Sample plots or enclosures will be evaluated to determine overwinter survival from the eyed egg to emergent fry stage. These will be monitored during the spring pre-emergent and emergent phase.

Periodic stream surveys will be conducted during the spawning runs to determine adult spawner density and species composition. Stream life studies will also be conducted concurrent with this adult portion of the evaluation project.

C. Schedule

See "Objectives" above.

D. Technical Support

Technical support will come from Department of Natural Resources, Department of Fish and Game, and Dryden Instrumentation (environmental engineers).

E. Location

The project site is located in the West Arm of Port Dick, Southern Kenai Peninsula, Lower Cook Inlet.

PROJECT IMPLEMENTATION

The Alaska Department of Fish and Game will implement the project. A bid will be awarded through a competitive bid process for the actual channel construction. The Alaska Department of Fish and Game has the enhancement, restoration and fish cultural expertise to implement the instream restoration portion of the project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This instream habitat restoration project is the only EVOS related project on the Kenai Peninsula and Lower Cook Inlet currently being considered for further funding. There is no efforts to coordinate with other projects at this time.

FY 95 BUDGET (\$K)

Personnel	19.3
Travel	1.5
Contractual	3.3
Commodities	4.0
Equipment	2.0
Subtotal	30.1
Gen. Admin.	3.1
Total	33.2

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Montague Riparian Rehabilitation Monitoring Program

Project Number:	95139C
Restoration Category:	Habitat Protection (new)
Proposed By:	USFS
Cost FY 95:	\$46,200
Cost FY 96:	\$43,100
Total Cost:	\$89,300
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Commercial fishing

INTRODUCTION

In FY 94, the Cordova Ranger District received funding to construct 25 to 30 structures in streams flowing through clearcut areas on Montague Island. These structures were designed to improve fish spawning and rearing habitat, prevent erosion, and help restore the natural flows and stream features that existed prior to logging. The 1994 work also includes the improvement of 20 acres of riparian vegetation.

In FY 95, the District proposes to evaluate these structures, repair any damage that may have occurred, and assess changes in the aquatic habitat, stream channels, and substrates. The riparian vegetation work will also be evaluated.

NEED FOR THE PROJECT

While instream structures have been used successfully in the Pacific Northwest and in some of the smaller streams on the Cordova Ranger District, this will be the first time such structures have been placed on Montague Island. Because of the climate and topography, the streams on the west side of the island are subject to intense flows. Although we feel confident that the structures will hold up to the flows, the extreme conditions may have some unforeseen effects. This project is somewhat experimental because it is being carried out in a remote area by a small crew using hand tools. Most other restoration work has involved heavy equipment where road access has been available.

We need to evaluate the effectiveness of these structures. If the structures prove to be successful, the same methods could be used to treat streams in other logged areas on Montague Island. The scope of the present structure work has been limited mainly to Hanning Creek, but there are several other streams which could benefit from this type of activity if it proves successful.

This work might also prove effective in other logged areas in Prince William Sound. The Port Fidalgo area, for example, also has steep slopes, high rainfall, and streams with highly variable flows.

PROJECT DESIGN

A. Objectives

1. Determine the changes in channel structure, fish habitat, and substrate at each of the structure sites and in an untreated area downstream.
2. Assess the riparian vegetation work by determining the survival rate of planted seedlings and the effectiveness of tree thinning.

B. Methods

Changes in the stream channels will be evaluated by mapping pools, riffles, backwaters, and other features before and after construction. Depth and substrate sizes in each of these areas will be recorded. Fish habitat, such as spawning and rearing area, will be assessed. A 100-yard segment, downstream of the structures, will also be mapped to assess the cumulative effects of the structures upstream.

The effectiveness of the structures will subsequently be evaluated in several ways. Since some of the structures are meant to re-create pool and backwater areas lost due to logging, their success can be measured by an increase in these features. Other structures meant to disperse energy and help moderate flows can be assessed indirectly by changes in substrate sizes or the formation of bars and other depositional features.

To evaluate the effectiveness of the tree planting, the main objective would be to determine the percentage of seedling survival. The roots and crowns can also be examined to assess growth and health. Competition from other species, such as alder and salmonberry should be assessed as well. The effectiveness of thinning is more difficult to quantify. Generally, however, such factors as growth, sunburned stems, and windthrow should be noted so that a general assessment of the work can be made.

Monitoring should continue at least through 1997, although the workload should decrease after the first year. The effectiveness of the structures may be apparent only after several periods of high water. The success of the vegetation work will take much longer to fully assess.

C. Schedule

Monitoring of the structures during the first year should be done at high and low flows. Monitoring of the vegetation work can be done after the growing season.

April 1995	Prepare equipment, personnel, and perform other preliminary work.
May 1995	Monitor structures at high flow. Map stream channel effects at structures and areas downstream.
Mid-July 1995	Monitor structures at low flow. Map stream channel effects at structures and areas downstream. Assess use of fish habitat.
September 1995	Monitor use of spawning areas and other fish habitat. Assess vegetation. Input and analyze information. Complete reports.

D. Technical Support

All work can be carried out by USFS personnel. No outside technical support is needed. A silviculturist will be needed to help with the assessment of the vegetation work. A GIS specialist will be used for entering the information into the GIS system.

E. Location

Hanning Creek (ADF&G stream # 710) Blying Sound D-1, 2 quadrangle, R10E, T3S, section 2 SE 1/4; Swamp Creek (ADF&G # 739) Seward A-1 quadrangle, R12E, T1N, section 11, SE 1/4 and section 12, SW 1/4; and ADF&G streams 734, 735, 736, Seward A-2 quadrangle, R12E, T1S, section 4 NE 1/4 and section 33 SW 1/4.

PROJECT IMPLEMENTATION

To be carried out by the Cordova Ranger District USFS.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Not applicable.

FY 95 BUDGET (\$K)

Personnel	31.7
Travel	0.0
Contractual	4.2
Commodities	1.8
Equipment	3.5
Subtotal	41.2
Gen. Admin.	5.0
Total	46.2

Surveys to Determine Additional Oil Spill Effects and Recovery of Marine Bird and Sea Otter Populations in Prince William Sound

Project Number:	95159
Restoration Category:	Monitoring (continued)
Proposed By:	DOI
Cost FY 95:	\$426,800
Cost FY 96:	\$65,000 (data analysis and report writing only)
Total Cost:	\$491,800
Duration:	2 years (survey should be conducted every other year)
Geographic Area:	Prince William Sound
Injured Resource/Service:	Marbled murrelet, pigeon guillemot, black oystercatcher, harlequin duck, and sea otter

INTRODUCTION

The waters and shorelines of Prince William Sound (PWS) support abundant marine bird and sea otter (*Enhydra lutris*) populations throughout the year. Potential injuries to marine birds from exposure to the *T/V Exxon Valdez* oil spill included, but were not limited to, death, changes in behavior, and decreased productivity. Post-spill studies, identical to the one proposed here, suggested that the population abundance of several marine bird species and sea otters declined as a result of the oil spill. Using surveys by small boats, this project will collect additional information to monitor the distribution and abundance of marine birds and sea otters in PWS. These post-spill data will be compared to data collected previously in 1989-91, 1993, and 1994 to ascertain trends in marine bird and sea otter distribution and abundance in PWS. This project will benefit restoration of PWS by determining additional species that show a latent oil spill effect and whether populations that declined due to the spill are recovering and by identifying what species are still of concern.

NEED FOR THE PROJECT

Almost 30,000 bird and 900 sea otter carcasses were recovered following the spill. Based on modeling studies using carcass search effort, and population data, an estimated 300,000 - 645,000 marine birds were killed in PWS and the northern Gulf of Alaska by the oil spill. Garrott, et al estimated that 2,800 sea otters were also killed. These estimates are probably low because they only include direct mortality occurring in the first five months after the spill.

The U.S. Fish and Wildlife Service conducted boat surveys of marine bird and sea otter populations in PWS in 1972-73, 1984-85, and several years following the spill (1989, 1990, 1991, 1993, and 1994). Klosiewski and Laing documented overall declines in 15 species or species groups between 1972-73 and the years after the spill. When comparing population estimates with 1984 data, Klosiewski and Laing documented decline of six species or groups within shoreline habitats in the oiled zone relative to the unoiled zone.

Burns, using data from the boat surveys, documented declines in sea otter abundance in shoreline habitats of PWS following the spill. He also detected a continuing pattern of significantly lower sea otter densities in oiled coastal areas, suggesting that mortality in or displacement of sea otters from these areas occurred. Agler et al examined whether species shown to decline had recovered. Most species or groups showed no trends in population abundance since the *Exxon Valdez* oil spill, although results were inconclusive due to the few years of data available. In 1993, two new species showed a latent oil spill effect. Klosiewski and Laing used Monte Carlo simulations to examine the power of determining trends from these data. These simulations showed that the number of surveys conducted has a large influence on whether a trend can be detected.

This project has several benefits. Restoration of marine bird and sea otter populations requires population estimates to determine whether recovery is occurring or if declines are continuing. Agler et al also found additional populations declining that were not previously shown to be injured. This project will benefit marine birds and sea otters by revealing species that show continuing injury due to the *T/V Exxon Valdez* oil spill. Survey data from this project have been used for these purposes by investigators of other studies on pigeon guillemots, marbled murrelets, black oystercatchers, and sea otters.

PROJECT DESIGN

A. Objectives

The purpose of this study is to obtain population estimates of marine birds and sea otters in PWS to monitor the recovery of species whose populations may have declined due to the *T/V Exxon Valdez* oil spill and to determine whether additional species may still be declining as a result of the oil spill.

The specific objectives of this project include:

1. To determine distribution and estimate population abundance, with 95% confidence limits, of marine bird and sea otter populations in Prince William Sound during March and July 1995;
2. To determine whether the marine bird species whose populations declined more in oiled areas than in non-oiled areas of PWS have recovered;
3. To determine whether additional species begin to show oil spill effects;
4. To examine the relative abundance of common species groups over time;
5. To support restoration studies on harlequin duck, black oystercatcher, pigeon guillemot, marbled murrelet, and sea otter by providing data on population changes, distribution, and habitat use of PWS populations; and
6. To examine the temporal variation in populations of marine birds in small index areas (i.e., Chenega, Tatitlek).

B. Methods

1. **Study Area:** Prince William Sound is a large embayment of the northern Gulf of Alaska. The rugged coastline is dominated by the Chugach Mountains, which drop precipitously to the shoreline in an intricate pattern of fjords and bays. Including the mainland and more than 150 islands, PWS contains over 5000 km of shoreline. The depth of PWS varies from <1 fathom (2 m) on Middle Ground Shoal to >475 fathoms (870 m) east of Lone Island. The study area includes all water within PWS, as well as land within 100 m of the shoreline. The waters on the Gulf of Alaska side of Montague, Hinchinbrook and Hawkins Islands, as well as Orca Inlet, are excluded.
2. **Sampling Methods:** Survey methodology will remain identical to that of post-spill surveys conducted in 1989, 1990, 1991, 1993, and 1994. We will conduct two surveys during 1995. We will use three 25-foot fiberglass boats, which are currently under U.S. Fish and Wildlife Service jurisdiction, to survey transects over a three week period during March and July 1995.

We plan to redesign the sampling design of the survey to increase precision of our estimates. We will continue to use a stratified random sampling design containing 3 strata, shoreline, coastal-pelagic, and pelagic. Instead of dividing the Sound into 5-minute latitude-longitude blocks as in the past, we will divide the area into one minute latitude by 2-minute longitude blocks to determine the starting points for our transects. We have used a similar design in surveys of Lower Cook Inlet and Southeast Alaska. At the latitude of the study area, the blocks of the grid will be approximately 1 nautical mile (nm) square. In the same amount of time, we will be able to sample many more of these

short transects, which will allow us to cover more area and should provide greater precision of our population estimates.

Temporal studies will be conducted annually in a limited area near both Chenega and Tatitlek by local people. Surveys would be conducted every month, January-December, as close to the first of the month as weather permits.

3. **Data Analysis:** As in previous surveys, we will use a ratio estimator to estimate population abundance. Population estimates for each species will be combined with other post-oil spill population estimates to determine population trends. Regression analyses will be used to determine the recovery of injured species and population changes of other species.

C. Schedule

Jan - Feb 95	Hire personnel, make logistical arrangements for winter survey
Mar 95	Conduct winter survey in PWS
Apr 95	Return to Anchorage, enter data, and store equipment
May 95	Hire personnel, make logistical arrangements for summer survey
July 95	Conduct summer survey in PWS
Aug - Sept 95	Analyze data from 1995 surveys

D. Technical Support

All technical aspects, such as GIS, will be conducted by project personnel; therefore, outside technical support is not needed.

E. Location

This study will be conducted in PWS. The study area includes all water within PWS, as well as land within 100 m of the shoreline.

PROJECT IMPLEMENTATION

The Division of Migratory Bird Management (MBM) of the U.S. Fish and Wildlife Service has conducted several surveys to estimate the population abundance and distribution of marine birds and sea otters in PWS. Surveys were conducted prior to the *Exxon Valdez* oil spill during 1972-73 and 1984-85, and for several years after the oil spill (1989-91, 1993, and 1994). MBM also has conducted several other studies within PWS. MBM has monitored reproduction of black-legged kittiwakes for over ten years and has been conducting research in PWS on marbled murrelets, pigeon guillemots, and black oystercatchers for several years. During 1994, MBM staff will also participate in a coordinated effort with NOAA to study forage fish within PWS.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will provide valuable information on the distribution and habitat use of marine birds and sea otters in PWS. This project is being coordinated with other DOI-FWS and NBS seabird monitoring studies in PWS and elsewhere (i.e., Lower Cook Inlet, Southeast Alaska). Survey data from this project will be available for use by investigators of other studies on marbled murrelets, black oystercatchers, pigeon guillemots, black-legged kittiwakes, forage fish, and sea otters.

FY 95 BUDGET (\$K)

Personnel	202.2
Travel	14.0
Contractual	111.0
Commodities	34.5
Equipment	27.0
Subtotal	388.7
Gen. Admin.	38.1
Total	426.8

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Abundance and Distribution of Forage Fish and Their Influence on Recovery on Injured Species

Project Number:	95163
Restoration Category:	Research (continuation of 94163)
Proposed By:	NOAA
Cooperating Agencies:	ADFG, DOI
Cost FY 95:	\$1,294,600 (includes \$173,600 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$285,400
Total Cost:	Unknown
Duration:	6 years
Geographic Area:	Prince William Sound and adjacent Gulf of Alaska waters
Injured Resource/Service:	Multiple resources

INTRODUCTION

A better understanding is needed of how prey availability affects distribution, abundance, growth and reproductive success of apex predators. Efforts to restore predatory species affected by the oil spill, particularly harbor seals, pigeon guillemots, marbled murrelets, common murre, black-legged kittiwakes, and salmon, could be delayed or completely unsuccessful without understanding distribution, abundance, and availability of important forage fish including herring, pollock, sand lance, capelin, and invertebrate species including macrozooplankton and squid.

NEED FOR THE PROJECT

This is the core project of the ecosystem project, Food Limitation on Recovery of Injured Resources: An Ecosystem Approach to the Restoration of Marine Birds and Mammals, a multi-disciplinary project designed to understand the Prince William Sound food web and the associated effects on the injured species.

This project will concentrate on determining distribution, abundance, and availability of important prey species (e.g., herring, pollock, sandlance, capelin, macrozooplankton, squid) to predatory species affected by the oil spill (i.e. harbor seals, pigeon guillemots, marbled murrelets, common murres, black-legged kittiwakes, and pink salmon). Diet overlap and prey selection among forage fish species will also be examined. This information, trophic position and niche overlap among species, will be used to establish the basic structure of future ecosystem models. The models of changing oceanographic regimes and prey species productivity and distribution would be necessary for understanding recovery of predatory species, and useful in guiding recovery activities.

PROJECT DESIGN

The forage fish project will evaluate existing field methods used in determining distribution, abundance, availability and class composition of forage fish. Provisions will be included to model affects of changing oceanographic regimes on forage fish species' distribution, abundance, and productivity.

The 1995 sampling program will be an expansion of the 1994 pilot project (94163) to determine distribution, densities and species composition of forage fish species. This project will also provide information on sex, age, growth, food habits, recruitment, and mortality of forage fish species. Field surveys will determine where apex predators forage and the distribution, abundance, and availability of forage fish of both nearshore and offshore waters within Prince William Sound and adjacent Gulf of Alaska waters. Ecosystem models to estimate biomass and productivity of forage fish species will be evaluated, and begun to be developed.

A. Objectives

This project will determine temporal and spatial distribution, abundance, and availability of important prey species (e.g., herring, pollock, sandlance, capelin, macrozooplankton, squid) in Prince William Sound and adjacent Gulf of Alaska waters. It will attempt to determine how important biotic and abiotic factors affect both short- and long-term distribution and abundance of prey species in the oil spill area. It will also determine how predator distribution, abundance, and foraging strategy coincide with forage fish distribution and abundance.

In 1995, the project's objectives are:

1. Evaluate existing field methods used in determining distribution, abundance and availability of forage fish.

2. Determine temporal and spatial distribution and abundance of prey species using hydroacoustic surveys and net sampling.
3. Investigate the relationships between forage fish abundance and distribution with oceanographic parameters.
4. Initiate development of ecosystem models to understand factors influencing distribution, abundance, and composition of forage fish.
5. Investigate relationships of forage fish abundance to marine birds and mammal abundance and productivity, in conjunction with complementary studies directed towards these species.
6. Determine forage fish prey using stomach content analysis for fish collected from nearshore and offshore sites, and estimate degree of diet overlap among species.

B. Methods

This project will ground-truth existing field methods used in determining distribution, abundance and availability of important prey species. It will conduct both coarse and fine scale hydroacoustic surveys and determine forage fish composition and sizes by net sampling. Coarse scale surveys will consist of line transects spaced throughout PWS. Fine scale surveys will occur at two to four locations known to be sea bird or marine mammal feeding areas. Both coarse and fine scale surveys will be conducted at least monthly from April through August. Four permanent hydroacoustics stations will be established to observe temporal patterns in prey abundances within and between years.

During hydroacoustic surveys, simultaneous bird and mammal surveys will take place from the same vessel(s). Data from this study will be combined with data from other seabird studies to compare relative fish abundance to foraging behavior and reproductive success of marbled murrelets, pigeon guillemots, and black-legged kittiwakes.

Forage fish will be sampled in nearshore and offshore areas using nets. Each species will be identified and length and weight measured on a minimum of 150 individuals randomly selected in each sample. Fifteen fish from each species will be preserved from each sample for later analysis of stomach contents. Additional samples will be collected for later lipid and stable isotope analysis.

C. Schedule

The forage fish surveys will be conducted under contract. The contractor work will conduct hydroacoustic and net sampling surveys at monthly intervals from spring to late summer. Annual reports will include progress on refining the forage fish models. A project status report will be submitted by the contractor in December 1995 which will discuss existing field methods

used in determining distribution, abundance, and availability of important prey species, and the process and justifications for selected survey techniques. The report will present and discuss the results of the field surveys including locations of forage fish and, when possible, the biomass of these species, and forage fish prey as determined from stomach content analysis. The contractor, in collaboration with NOAA, ADFG and USFWS, will report on the correlation of forage fish distribution and abundance with marine birds (marbled murrelet, pigeon guillemot, black-legged kittiwake) and mammal abundance and productivity. The report will also describe and evaluate ecological models to estimate productivity of important prey species, and a sampling program to fulfill requirements of ecological models. Annual reports will include progress on refining the productivity models.

Field Studies

April - August 1995

Contractor field sampling

Laboratory & Data Analyses

June 1 - December 31, 1995

Conduct stomach contents analysis

January 1, 1996 - March 31, 1996

Analyze data and prepare annual report due within four months after cruise; submit draft annual project report

D. Technical Support

This project will generate data which will be useful to the monitoring projects and studies currently underway in Prince William Sound. In order to insure access to these data, the information collected from this project will be incorporated into a data base managed by the Trustee Council.

E. Location

This project will concentrate its initial activities within Prince William Sound. However, some sampling design feasibility work may be performed in Gulf of Alaska waters adjacent to Prince William Sound.

PROJECT IMPLEMENTATION

This project will be contracted and coordinated by NOAA with cooperative components conducted by ADFG and USFWS.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will be highly integrated with several components of the SEA Program and several of the marine bird and marine mammals projects. The Physical Oceanography, Nearshore Fish, Zooplankton, and Phytoplankton components of SEA will collect data relevant to forage fish

distribution and production. Within the SEA Physical Oceanography component, conductivity-temperature-depth (CTD) profilers and Acoustic Doppler Current Profilers (ADCP) will be deployed from a mid-water trawl vessel. Within the SEA Nearshore Fish component, hydroacoustic data will be obtained in offshore habitats from a mid-water trawl vessel and in nearshore habitats from small hydroacoustic survey boats. Within the SEA Zooplankton and Phytoplankton components, zooplankton and water samples will be collected using nets and water bottles. The Salmon Growth and Salmon Predation components of SEA will collect forage fish samples for later stomach contents analysis in offshore and nearshore habitats using mid-water trawls, and beach and purse seines. Age-weight-length data will be collected from the forage fish to accompany hydroacoustic data. All data collected as part of SEA will be provided to the Information and Modeling component for use in development and implementation of ecosystem models.

The forage fish study and the marbled murrelet, pigeon guillemot, and kittiwake studies will provide complementary and integral information to determine if food is limiting the recovery of sea bird species. Data on seabird foraging and reproductive parameters will be compared to the forage fish assessment data to investigate the relationship of food availability or limitation to seabird productivity.

FY 95 BUDGET (\$K)

Personnel	274.2
Travel	24.3
Contractual	882.3
Commodities	7.4
Equipment	26.0
Subtotal	1214.2
Gen. Admin.	80.4
Total	1294.6

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Herring Natal Habitats

Project Number:	95166
Restoration Category:	Monitoring (continuation of 94166)
Proposed By:	ADFG and University of Alaska Juneau
Lead Trustee Agency:	ADFG
Cost FY 95:	\$512,800 (includes \$238,600 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$457,500
Total Cost:	Unknown
Duration:	6-8 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring

INTRODUCTION

This project provides a direct measure of Pacific herring *Clupea pallasii* abundance that is vital to monitoring recovery of the injured PWS herring population. It also provides information about survival of herring eggs and information necessary for interpretation of previous oil spill damage assessment results and improvement of our understanding of long term damage. In addition, abundance estimates from this project are used to set commercial harvest strategies, thereby contributing to the recovery process for PWS herring populations.

Studies of oil spill injuries to herring were initiated in 1989 and continued through 1992 with contributions from both state general funds and the Trustee Council. Oil spill injuries were documented, primarily to embryo and juvenile life stages. PWS herring attained historic high population levels in the four years following the spill, and EVOS herring studies were not conducted in 1993. In 1993 the herring population unexpectedly crashed and population declines continued into 1994. Herring are currently listed as not recovering. Spawn deposition surveys, estimates of eggs lost due to predation and wave action, and laboratory studies of reproductive impairment were conducted in 1994 under Trustee Council funding. Spawn deposition surveys are currently considered the best available method for estimating population abundance. Surveys should continue for one recruitment cycle (4 years) or until the efficacy of an alternative abundance estimation method is proven.

NEED FOR THE PROJECT

Pacific herring are a major resource in Prince William Sound (PWS) from both commercial and ecological perspectives. Five commercial herring fisheries in PWS have an average annual combined ex-vessel value of \$8.3 million. Pacific herring provide important forage for many species including some species severely injured by the *Exxon Valdez* oil spill. Predator species include humpback whales, seals, sea lions, gulls, sea ducks, shorebirds, halibut, salmon, rockfish, and other fish. In addition, several thousand pounds of herring and herring spawn on kelp are harvested annually for subsistence purposes and form an important part of the local native culture.

In 1993, the total observed spawning population of PWS herring was less than one third of preseason predictions and the average sizes of herring in each age class were some of the smallest on record. Only limited commercial herring fishing occurred. Preliminary pathology results implicated viral hemorrhagic septicemia (VHS) as a potential source of mortality and stress. In 1994, as in 1993, the spawning population was again below pre-season predictions. Aerial surveys indicated the population was less than minimum threshold harvest levels and no commercial fishing was allowed. The ex-vessel value of the herring fisheries in 1992 was \$12.0 million. In 1993, the ex-vessel value dropped to \$2.0 million and no commercial harvest occurred in 1994. This project will enable resource managers to better understand herring population dynamics to improve the recovery process. In addition, it will aid local resource users to make appropriate pre-season plans based on accurate and precise herring return projections.

In response to the low apparent return, a comprehensive pathology study was initiated in 1994 to determine whether VHS plays a role in the apparent decline in the herring spawning population and to try to determine the magnitude of the effect. It is not clear whether the *Exxon Valdez* oil spill may be implicated, although numerous studies have indicated that previous exposure to toxins can reduce immunity to disease. Continuation and completion of the pathology study is being proposed for FY95. Population abundance information from spawn deposition surveys is prerequisite for meaningful interpretation of pathology results.

The cost of this project is reasonable considering the economic value of the commercial fisheries as well as the important contribution that herring of all life stages make to the PWS ecosystem.

PROJECT DESIGN

This project will be conducted in several parts. ADFG will perform the field component constituting the continuation of herring spawn deposition surveys and egg loss studies in PWS. New elements for this component will include: (1) digitizing of historic spawn distribution information into geographical information system (GIS) format and development of descriptive measurements appropriate for analysis of spawning habitat use, (2) estimation of the incidence of cytogenetic abnormalities occurring in hatching herring, (3) modeling of embryo survival and recruitment in relation to biological and environmental variables. Prince William Sound

Science Center will be contracted to perform the spawn map digitizing. Dr. JoEllen Hose with Occidental University will perform the cytogenetic abnormality examinations and data analyses. Dr. Terry Quinn with the University of Alaska, Juneau, will oversee the modeling.

During spawn deposition surveys, SCUBA divers will estimate the abundance and distribution of herring eggs. This information will be incorporated with aerial observations of spawn distribution and basic biological information collected as part of ongoing ADFG studies (age composition, sex ratios, average size, and fecundity) to estimate adult spawning biomass. Estimates of spawning biomass are used to forecast spawning returns the following year and form the basis of herring fishery management in PWS. New and existing data will be used to develop a classification system for spawning habitat types. Habitat use and spawner/egg density and distribution data collected during this project are needed to develop herring embryo survival models outlined in the Natal Habitat Program (NHP) of Sound Ecosystem Assessment (SEA).

The egg loss study will provide estimates of herring embryos physically removed from spawning areas by predation and wave action. Estimation of egg loss is useful (1) to improve accuracy of biomass estimates by accounting for eggs lost between the time of spawning and the time of spawn surveys and (2) as an important element in the estimation total embryo survival. Total embryo survival to the larval life stage is necessary as an initial population abundance input for life history models described in SEA. Improved understanding of larval production dynamics is also an important adjunct to improving our understanding of processes affecting herring recruitment.

Factors directly affecting survival of embryos to larvae include losses due to wave action and predation, desiccation at low tide, cytogenetic abnormalities (which result in nonviable hatched larvae), pathogens, and pollution (which may elevate cytogenetic abnormality levels). These sources of direct mortality may be modified by environmental and biological variables such as wind direction and severity of storms, number of predators present and the availability of eggs to predators, the type of substrate on which eggs are deposited, height of tidal fluctuation, water temperature, and air temperature. The degree to which these modifiers of direct mortality affect survival depends largely on the characteristics of the habitat used for egg deposition. Because it is not practical to measure all sources of mortality each year, total embryo survival models will be used to relate mortality to more easily measured or estimated environmental and biological variables and habitat selected.

A. Objectives

1. Estimate the biomass of spawning herring in PWS using SCUBA diving spawn deposition survey techniques such that the estimate is within $\pm 25\%$ of the true value 95% of the time.
2. Quantify egg loss rates (the proportion of eggs removed through time) from spawning areas due to wave action, predation, desiccation, or fungal infections between the time of egg deposition (spawning) and the time of hatching. Quantify egg loss by habitat type and egg density.
3. Incorporate egg loss and egg survival estimates with results from previous studies and revise the models as necessary.
4. Describe herring spawning habitat with respect to temperature, salinity, depth, gradient, substrate, vegetation, and exposure to wave action. Map habitat historically utilized for spawning. Estimate habitat specific abundance and distribution of adult herring and eggs. Test a model of the relationship of spawn timing, spawner density and abundance to egg distribution and density.
5. Incorporate egg loss and survival data with physical oceanographic and meteorological data to formulate and test a model of the relationship of meteorological conditions to wave height and egg desiccation.
6. Test a model of the relationship between predation, wave action, desiccation, fungal infections, egg density, and habitat utilized.
7. Test a model relating sound-wide embryo survival to habitat utilized, egg density, and meteorological conditions.
8. Test a model relating historic recruitment success to biological and environmental variables.

B. Methods

Biomass estimation based on spawn deposition surveys consisted of three major components: (1) a spawn deposition survey; (2) age-weight-length (AWL), sex ratio, and fecundity sampling; and (3) egg loss determination.

Spawn Deposition Surveys. Survey design was described in detail by Biggs and Funk, and follows closely the two-stage sampling design of similar surveys in British Columbia and Southeast Alaska. Surveys will use random sampling for the first stage (transects) and systematic sampling for the second stage (quadrats within transects). Surveys will be stratified by area to account for geographic differences and the potential for discrete herring stocks.

Mean egg densities along each transect will be combined to estimate an average egg density by area. Spawning bed width along each of the transects will be used to calculate average spawning bed width by area. Average width, average density, and total spawning bed shoreline length will be used to estimate total number of eggs deposited in each area. Average fecundity, sex ratio, and estimates of total number of eggs deposited will be used to calculate herring population numbers and biomass. Confidence intervals will be calculated assuming a normal distribution of total egg estimates.

The general location of spawning activity will be determined from milt observed during scheduled aerial surveys. This information will be used to randomly select and locate transects. Each transect will be assigned a sequential number and charted on waterproof field maps.

Diving on herring spawn will begin after spawning has ceased. Two three-person dive teams will complete approximately six to twelve transects each day to achieve sample goal of about 100 transects. The sample goal of selected transects will be established based on the total length of beaches receiving spawn and variability observed in previous surveys.

Using a 0.1 m² PVC pipe frame for a sampling quadrat, the number of eggs, substrate, and vegetation type will be estimated for quadrat locations systematically spaced every 5 meters along a transect until the apparent end of spawn. Samples of eggs and vegetation will be used to correct for diver bias. These diver calibration samples will be collected throughout the dive survey and stratified by diver, vegetation type, and by egg density.

Estimates of the biomass of spawning herring will be calculated from estimates of deposited eggs, fecundity, sex ratio, average size, and age composition similar to methods described by Biggs and Funk and Biggs et al. Predictions of returning biomass in the following year will be estimated using methods similar to those described by Funk (1994).

Herring Age, Weight, Length, Sex, and Fecundity. This portion of the project is part of an existing agency program that is conducted annually by ADFG. AWL information will be collected from major concentrations of herring spawning in each area. AWL sampling will be stratified by date and area for each commercial fishery and for test fishing catches in each spawning area. A sample size of 450 herring per stratum will be set to ensure acceptable levels of precision and accuracy. Fecundity samples will be subsampled from among female herring AWL samples and stratified by fish length. Egg and gonad weights will be measured and used to calculate average fecundity at an average female weight. Gonad weight will be used to estimate gonadal somatic index (GSI), a measure of relative maturity defined as the percentage of total herring weight accounted for by gonad weight.

Mean weight and sex ratio will be estimated from AWL samples collected from each of the five spawn deposition summary areas. AWL samples collected during peak spawning in each area will be pooled to estimate mean weight and sex ratio for that area. Average weight and sex ratio for PWS will be estimated as a weighted average of estimates from all areas. Average weight and sex ratio for each area will be weighted by the escapement biomass estimate based on spawn deposition surveys for that area.

Egg Loss. Egg loss was studied during 1990 and 1991 in PWS and an average daily egg loss rate of 2.1% and an average total egg loss of 50.4% over the 22.5 day incubation period were reported. Previous studies did not include collection of data to relate egg loss to habitat type, environmental conditions, or predation. The current study will include modifications to sampling design to improve understanding of these mechanisms behind egg loss. This information and previous results will be used to model embryo survival. Egg loss transects will be established in two areas chosen to represent major spawning areas and will be located within areas to represent typical habitats selected for spawning. PVC pipe grids of 5 x 2 permanent 0.1 m² quadrats will be placed along each transect at depths within the range of usual herring spawn. Each transect will be visited every three to four days and divers will make estimates of egg density within each 0.1 m² quadrat.

A sample containing about 200 eggs will be collected adjacent to each frame during each visit at each depth. Live/dead ratios will be estimated and the eggs will be examined for any signs of egg desiccation and fungal infection. Just prior to hatch, a subsample of live embryos collected for live/dead examination will be immersed in preservative for later evaluation of morphological abnormalities and cytogenetics.

Exclusion frames of approximately 1 m³ in volume will be placed at representative transect locations to exclude avian predators. The total count of eggs within each frame will be estimated each time the site is visited to estimate the number of eggs consumed by birds. These data will contribute prey availability information to the avian predation on herring roe component of SEA.

Physical measurements including air and water temperature, salinity, precipitation, wind speed and direction, and tide height will be collected at each site during each visit. Measurements of gradient, substrate and vegetation will be collected once when the site is set up. Regional meteorological and oceanographic data will be obtained from shipboard surveys, moored instrumentation, and existing data products from government agencies. These measurements will be used to model the effect of meteorological conditions on egg loss and embryo survival.

Egg Loss Data Analysis. An exponential decay model will be used to estimate loss in numbers of eggs over time corrected for diver bias. Egg loss and egg survival estimates will be synthesized into an embryo survival model that incorporates habitat type and predation. Preliminary analysis of previous egg loss data and embryo survival modeling will be completed in FY 94 and will be used to formulate specific sampling design modifications for FY 95.

C. Schedule

Jul - Sept 94	Egg loss data analysis and embryo survival modeling
Aug 94	Complete Detailed Project Description
Dec 94	Complete FY94 progress report
Nov 94 - Feb 95	Initiate vessel charter bids and contract Secure divers, ensure certification requirements are met or in progress Complete data review and sample design for egg loss study Complete sample design for diver calibration
Mar 95	Complete any necessary diver certifications Order laboratory supplies and field supplies Hire personnel to maintain and assemble dive gear
1-5 Apr 95	Complete all hiring of field personnel and arrange for arrival of divers Vessel arrives on site for inspection
1-4 Apr 95	HazMat, CPR/First Aid and Dive Safety training; Project orientation Set up laboratory
5-15 Apr 95	Initiate diving/field data collection (at onset of spawning) Set up egg loss sites and begin diving
1-15 May 95	Complete field activities Begin lab processing of calibration, fecundity, and egg loss samples
30 May 95	Complete data entry of diver estimates
May-Jun 95	Maintain, repair, and store gear
15 Jun 95	Complete calibration sample processing
30 Jun 95	Data entry of calibration samples Initiate data analysis
15 July 95	Complete egg loss sample processing and data entry
15 Aug 95	Preliminary biomass estimate
1 Sep 95	Finalize estimate of spawning biomass
15 Nov 95	Finalize projection of 1995 run biomass
Dec 95	Complete annual reports

D. Technical Support

ADFG regional and headquarters biometric staff will assist in project planning, review, and reporting for this project. They will also provide primary assistance for analysis of spawn deposition data and generation of biomass estimates using partial funding from this project. Additional biometric and modelling assistance for egg loss data analysis will be obtained through hiring and half time funding for a Biometrician I with ADFG. Remaining biometric and modelling assistance will be contracted through a Cooperative Service Agreement (CSA) or a Reciprocal Service Agreement (RSA).

Primary databases and analytical files will be stored on the local area network (LAN) of the Cordova ADFG office and technical assistance for database management for FY94 will be provided by the Cordova office network administrator. Some database management needs will be accommodated through funding for a research analyst or equivalent part time position beginning in FY95. In addition, we will coordinate with the SEA plan data managers to ensure that future incorporation and integration with their system can be accomplished.

Laboratory services will be completed at the Cordova ADFG office with the exception of some collections of intertidal invertebrates and fishes, and samples collected for cytogenetic analysis. The intertidal predator samples will be transferred to the Copper River Delta Institute of the USFS to complete their research objectives. Analysis of cytogenetic samples will be subcontracted in FY95.

E. Location

This project will be conducted entirely within PWS and it is expected that project results will directly affect the management of PWS herring fisheries. The communities directly affected that house fishermen, vessels involved in the fisheries, processing plants, and support services for the fisheries include Cordova, Seward, Valdez, and Whittier. The subsistence harvests of the native villages of Tatitlek and Chenega will also be directly affected.

PROJECT IMPLEMENTATION

ADFG has the experience and resources to perform the field work associated with this project. Regular ongoing herring research activities conducted by ADFG are an integral part of the data collection. Biometric assistance and laboratory analysis will be provided by ADFG staff or obtained through a RSA with the University of Alaska, Juneau, through Dr. Terrence Quinn. A major component of egg loss, avian predation, will be estimated through a companion project conducted by the Copper River Delta Institute as a component of SEA.

Dr. JoEllen Hose, Occidental College, Los Angeles, CA will be contracted to perform cytogenetic analysis of herring larvae. Dr. Hose developed the techniques used to analyze oil spill damage to PWS herring and is the logical choice for this contract due to her experience with these data.

Digitizing of historic spawn maps may be done by Dr. David Scheel with the Prince William Sound Science Center under a CSA or obtained through competitive bid process.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The proposed study is a continuation of damage assessment studies begun in 1989. In addition, it is a major component of the integrated Prince William Sound Ecosystem Assessment (SEA) investigation initiated in 1994. This project provides the basic estimate of population abundance necessary to completion of most other herring research components. Estimates of total embryo survival from modeling of egg loss/mortality studies, habitat studies, and an avian predation study form the initial inputs for herring life history based models integral to SEA. Herring recruitment modeling portions of the proposed study will provide information about critical life stages needed to refine project design of the juvenile herring trophics and habitat partitioning study component of SEA.

This project will also share information and resources with the herring genetic stock identification study.

Integration of research will require data sharing and coordination with PWS forage fish studies. Because herring are an important forage species, their abundance and distribution information must be integrated with the composition, abundance, and distribution information of other fish species. Because herring and other forage fish may be potential predators, competitors, and prey for each other at various stages throughout their life histories, understanding their respective population structures will improve our understanding of herring early life history and recruitment.

Two other projects, disease impacts on PWS herring populations and reproductive impairment of PWS herring, will require sharing of research platforms and extensive exchange of data and results.

FY 95 BUDGET (\$K)

Personnel	195.7
Travel	4.8
Contractual	248.6
Commodities	11.9
Equipment	5.1
Subtotal	466.1
Gen. Admin.	46.7
Total	512.8

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Factors Affecting the Recovery of Prince William Sound Pigeon Guillemot Populations

Project Number:	95173
Restoration Category:	Research (continuation of 94173)
Proposed By:	DOI
Cost FY 95:	\$408,800 (includes data analysis and report writing costs)
Cost FY 96:	\$360,100
Total Cost:	\$1,889,600
Duration:	5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pigeon guillemot

INTRODUCTION

The population of pigeon guillemots (*Cepphus columba*) in Prince William Sound (PWS) has decreased from about 15,000 in the 1970s to about 3,000 in 1993. There is evidence suggesting that this population was in decline before the *Exxon Valdez* oil spill in March of 1989. An estimated 2,000 to 3,000 pigeon guillemots were killed throughout the spill zone during that event. Censuses of guillemots conducted before and after the spill indicated that pre-spill counts (ca. 2,000) in the study area (Naked Island and vicinity) monitored during Bird Study Number 9 were roughly twice that of post-spill counts (ca. 1,000). Also, relative declines in the populations of guillemots were greater along oiled shorelines than unoiled shorelines. Latent effects from the spill might still be affecting the population because guillemots do not breed until three or four years of age.

Adult guillemots delivered schooling fish, particularly sand lance (*Ammodytes hexapterus*), to their chicks less frequently after than before the spill suggesting a possible food-related component to their decline. Predation of eggs and chicks, apparently not important previously, might now play a greater role in the lower reproductive success of guillemots observed by Oakley and Kuletz.

This study is a continuation of the pigeon guillemot Recovery Monitoring Project (No. 94173), and an extensive survey of pigeon guillemot colonies in PWS (Project No. 93034). Bird Study Number 9, begun in 1989 immediately after the oil spill, compared various population and reproductive parameters of pigeon guillemots measured both before and after the spill.

The goal of the present study is to determine whether food, predation, direct toxicity from oil, or adult mortality is limiting the recovery of the pigeon guillemot population in PWS.

Information on the abundance and distribution of schooling fish collected by the forage fish project (No. 94163), in conjunction with our own studies of the guillemots' diet and foraging habits, will help us address the question of food as the limiting factor.

NEED FOR THE PROJECT

Considerable baseline data on pigeon guillemot populations and foraging and reproductive ecology in PWS have been collected both before and after the oil spill. Continuation of these efforts is essential to determine what factors are limiting the recovery of this species. Food supply, predation, or oil toxicity might limit reproductive success. This project will evaluate the relative importance of these three factors.

PROJECT DESIGN

A. Objectives

1. Determine if the availability of food is limiting reproductive success by:
 - a. Measuring breeding phenology, egg volume, chick growth rates, fledgling weights, and reproductive success at colonies on Naked Island and at least one other area determined in the 1994 field season.
 - b. Measuring diet and provisioning rates of chicks, duration of foraging trips by parents, and location of foraging areas.
 - c. Assessing forage fish abundance in guillemot feeding areas (forage fish project).
 - d. Assessing abundance of nearshore demersal fishes.
2. Determine if predation on eggs or chicks is limiting reproductive success by measuring relative rates of predation during the egg and chick stage, in different nesting habitats, and at different colonies.

3. Determine if direct toxicity of oil is limiting reproductive success by determining if there is persistent oiling of guillemot eggs.
4. Determine if adult survival and recruitment is limiting recovery of the PWS guillemot population by observing returns of color-marked birds.

B. Methods

Reproductive success will be monitored using standard field techniques involving periodic nest checks. Morphometric data for determining growth rates will be acquired at regular intervals during the chick-rearing period.

Provisioning rates and diets of chicks will be determined whenever possible throughout this period by observing them from strategically located blinds. Radio-tagged birds will be tracked to their foraging grounds.

Predation rates will be recorded for all known nests. Time-lapse videography or that triggered by infrared sensors will be used in an attempt to document predation and identify predators as well as monitor activity budgets of chick-rearing guillemots.

An approved protocol will be used to collect unhatched eggs to be stored and shipped in sealed jars for hydrocarbon analysis. Estimates of adult survival will require the successful marking of breeding adults with color bands during the 1994 and 1995 (and any future) field seasons. Because of the high degree of nest-site fidelity in pigeon guillemots, known breeding birds not sighted the following season will be assumed to be dead. Marked birds are also useful in determining sex, activity budgets, and reproductive histories of individual birds.

C. Schedule

Oct - Dec 94	94173 data analysis
Dec - Jan 95	94173 report writing
Feb 15, 95	94173 draft report
Mar 31, 95	94173 final report
May - Aug 95	Field work/data collection
Sep - Nov 95	95173 data analysis
Dec - Jan 96	95173 report writing
Feb 15, 96	95173 draft report
Mar 31, 96	95173 final report

D. Technical Support

Hydrocarbon analysis will be contracted to Texas A&M University.

E. Location

Naked Island and vicinity, which is surrounded by a shallow shelf, supports only about one fourth of the PWS Pigeon Guillemot population. Because the 1993 pigeon guillemot colony survey showed that Naked Island is not representative of all habitats utilized by guillemots in Prince William Sound, at least one other area selected during 1994 field season will be studied. The other study area(s) will be chosen based on the following criteria: (1) existence of a relatively large number of breeding guillemots, (2) accessibility of nest sites for monitoring, and (3) bathymetric characteristics (deep water relative to that of Naked Island).

PROJECT IMPLEMENTATION

The USFWS is the most appropriate entity to conduct this project. The USFWS has conducted marine bird surveys and research in Prince William Sound, including studies of guillemots at Naked Island, since the 1970's, and is therefore well qualified to conduct this study. Barge transport of field equipment from Whittier to Naked Island, and hydrocarbon analysis are the only aspects of this project considered appropriate for contract bidding.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is integrally related to the NOAA forage fish project (No. 94163), and a proposed study of prey energetics that will be conducted via NOAA's Broad Agency Assessment (BAA). The forage fish project will assess the abundance of forage fish in key foraging areas, while the energetics project will provide information on the effects on guillemots of their feeding on prey of varied energetic values. Data from the present study, and the proposed kittiwake and puffin studies, will provide a three-pronged approach to addressing the question of food limitations on marine bird population recovery.

The guillemot project will share a field camp with some of the personnel from the proposed marbled murrelet, kittiwake, and puffin studies. Transport of equipment, communications with Anchorage, and data collection will be shared among these three projects. A coordinated effort among all the projects is expected throughout the lives of these biologically related studies.

FY 95 BUDGET (\$K)

Personnel	232.0
Travel	11.0
Contractual	85.0
Commodities	15.0
Equipment	25.0
Subtotal	368.0
Gen. Admin.	40.8
Total	408.8

Investigating and Monitoring Oil Related Egg and Alevin Mortalities (Field Study)

Project Number:	95191A
Restoration Category:	Research (continuation of 94191)
Proposed By:	ADFG
Cooperating Agency:	NOAA
Cost FY 95:	\$265,000 (includes \$68,400 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$324,900
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink salmon

INTRODUCTION

Each year approximately one half billion wild pink salmon fry emerge from the streams of Prince William Sound (PWS) and migrate seaward. Adult returns of wild pink salmon to PWS average from 10-15 million fish annually. These huge outmigrations of wild pink salmon and subsequent adult returns play a major role in the PWS ecosystem. Both juveniles and adults are important sources of food for many fish, birds, and mammals. Adults returning from the high seas also convey needed nutrients and minerals from the marine ecosystem to estuaries, freshwater streams, and terrestrial ecosystems. Wild pink salmon also play a major role in the economy of PWS because of their contribution to commercial, sport, and subsistence fisheries in the area.

Up to 75% of pink salmon spawning in PWS occurs in intertidal areas. In the spring of 1989 oil from the *T/V Exxon Valdez* oil spill (EVOS) was deposited in layers of varying thickness in intertidal portions of many western PWS streams utilized by spawning salmon. Pink salmon eggs and fry rearing in these intertidal areas appear to have been adversely affected by the oil. Salmon egg mortalities were 67%, 51%, 96%, 79%, and 59% higher in oiled streams than in comparable and nearby unoiled streams in 1989, 1990, 1991, 1992, and 1993, respectively. Differences between oiled and unoiled streams in 1989 and 1990 were confined to intertidal spawning areas and may be attributed to direct lethal effects of oil. Large differences observed

across all tide zones in 1991 and 1992 may be the consequence of damage to germ cells of the adults which originated from the 1989 and 1990 brood years when egg and larval exposures to intertidal oil were greatest. A consequence of this genetic damage may be persistent functional sterility and reduced returns per spawner for populations from oiled streams.

The proposed damage assessment and resource monitoring study is a continuation of past EVOS Trustee Council funded work conducted by the Alaska Department of Fish and Game (ADFG) and the National Marine Fisheries Service (NMFS). It will consist of field and laboratory studies conducted in western PWS and additional laboratory studies at the NMFS Research facility at Little Port Walter in southeastern Alaska. Results of the project will direct future restoration efforts for pink salmon and may impact future harvest management strategies in PWS fisheries.

The project will continue to monitor egg mortalities in the oiled and unoled wild pink salmon streams previously studied, examine stream characteristics unrelated to oiling which may partially or completely explain the observed differences in egg mortality, and provide a laboratory evaluation of the 1989 and 1990 field results. The laboratory evaluation will also test the hypothesis that oil contamination during incubation can result in functional sterilization.

NEED FOR THE PROJECT

Information gained from this study will provide resource managers insight to the magnitude and persistence of damages sustained by wild pink salmon due to EVOS. Efforts to restore damaged pink salmon populations depend upon the fishery manager's abilities to identify sources of reduced survival and to monitor their persistence. Information on the potential of long term oil exposures to cause genetic damage is needed so spawning escapement goals can be reevaluated and adjusted if necessary. In addition, verification of the genetic hypothesis would provide the first evidence that reproductive capacity of fish exposed to chronic or acute sources of oil pollution would be compromised.

PROJECT DESIGN

A. Objectives

Component A - Recovery Monitoring of Injury to Pink Salmon Embryos in PWS

1. Estimate the density, by tide zone, of embryos in 31 streams using numbers of live and dead eggs and fry.

2. Estimate mortality of pink salmon embryos in both oil contaminated and unoiled (reference) streams.
3. Assess any loss in adult production from changes in embryo mortality using results of past NRDA studies.

Component B - Evaluation of Injury to Pink Salmon Gametes in PWS

1. Determine whether the increased pink salmon embryo mortalities observed in oil contaminated streams in 1989, 1990, 1991, 1992 and 1993 can be attributed to the physical characteristics of study streams.

Component C - Laboratory Evaluation of Injury to Pink Salmon Embryos and Preemergent Fry Exposed to Oiled Incubation Substrate

1. Determine survival, genetic damage, hydrocarbon uptake, mixed function oxidase activity, and sublethal teratogenic effects from long term exposures to oil in eggs exposed from fertilization to emergence.
2. Determine growth characteristics from each exposure group from juvenile stage to maturity.
3. Assess whether differences exist among exposure groups with respect to fecundity, fertilization rate, genetic damage, and sub-lethal teratogenic effects in the second generation progeny through swim-up.

Combining Field Observations and Laboratory Results

1. Determine if the elevated embryo mortalities in 1989 and 1990 were potentially caused by oil in the environment.
2. Determine if the elevated embryo mortalities in oil contaminated streams in 1991 and 1992 were potentially caused by genetic damage to 1989 and 1990 embryos.

B. Methods

Component A - Recovery Monitoring of Injury to Pink Salmon Eggs and Preemergent Fry in PWS

A systematic sampling program stratified by stream and tide zone will be used to collect egg, embryo density and survival data from 10 oil contaminated and 15 reference sites sampled previously in NRDA Fish/Shellfish Study 2, Restoration Science Study R60C, and Restoration Science Study 93003. Sampling will consist of embryo sampling conducted in late September and early October. Egg and embryo data will be summarized by date, stream, level of hydrocarbon impact, and stream zone. Density estimates will be used to assess adult spawning

success. Relative numbers of live and dead embryos will be used to test for continued reductions in survival in oil contaminated streams.

Component B - Evaluation of Injury to Pink Salmon Gametes in Prince William Sound

This project will continue to monitor the incubation of the Intra-stream crosses made during Restoration Science Study 93003. Embryos from the crosses will be incubated through hatching in a controlled laboratory environment. Egg mortalities will be compared for all crosses. Crossing results will be compared to results from field studies to determine the effect of stream characteristics on egg mortality differences previously observed between oiled and unoiled sites.

Component C - Laboratory Evaluation of Injury to Pink Salmon Eggs and Preemergent Fry Exposed to Oiled Incubation Substrate

This project will evaluate the degree of damage to embryos incubating in oiled substrate and determine the subsequent effects on fertility. Incubating pink salmon embryos will be exposed to oiled gravel in incubators from fertilization to emergence. Surviving fry will be grown to maturity and crossed with partners incubated under the same dose of oil. Relationships between dosage and fertility will be observed in addition to relationships between dosage and developmental success.

Finally, the screening for petro-chemical induced microlesions and macrolesions will be completed on individuals of known oiling history (including unoiled controls). Emphasis will shift away from flow cytometric analyses this project year to focus on the techniques of 1) haploid androgenesis and 2) DNA sequencing of rapidly evolving regions of DNA. A contractor will screen for deleterious recessive mutations (recessives are to be expected in the tetraploid-derived genome) using haploid androgenesis. Peer reviewers have recommended that we use a PCR-based approach to sequence the control region of mtDNA to maximize the probability of detecting genetic damage. Other regions of DNA will be targeted based upon the results of the control-region screen.

C. Schedule

Component A:

Oct 1-15 1994	In stream embryo sampling
Oct 30-Dec 30 1994	Analysis of embryo data and completion of FY 93 final report

Component B:

Oct 1-Nov 15 1994	Monitor incubators and collect data
Nov 15 1994-Jan 30 1995	Analyze data and prepare annual report

<u>Component C:</u>		
<u>Time Period</u>	<u>1992 Brood Year</u>	<u>1993 Brood Year</u>
1 Sept 94 - 15 Apr 95	Incubate F1	Culture in netpens
15 Apr - 1 Sept 95	Analyze incubation data from F1, prepare report	Spawn mature adults
1 Sept 95 - 15 Apr 96	N/A	Incubate F1
15 Apr - 1 Aug 96		Analyze incubation data, prepare final report

D. Technical Support

The project biometrician will ensure that the study design will provide a reasonable chance of reaching a defensible conclusion. A DNA technician will ensure proper tissue collection and preparation procedures, operate the flow cytometer, and perform sequencing. Gary Thorgaard, Washington State University, will provide the laboratory and technical expertise to perform the androgenetic screen. A chemist is required to establish a dosing protocol, determine hydrocarbon concentrations, and evaluate results of hydrocarbon analysis. Contracts will be required for histopathological and mixed-function oxidase work. It is essential that the results of this controlled experimentation be consistent with the results gathered under NRDA.

E. Location

Component A. All embryo and preemergent fry monitoring will take place in Prince William Sound.

Component B The experiment designed to evaluate the effects of environment on egg mortality will collect gametes from streams in Western Prince William Sound and incubate the resulting embryos at the Armin F. Koernig hatchery in Prince William Sound.

Component C. The experiment designed to test the effects of oil contaminated incubation substrate on gamete viability will be performed at the National Marine fisheries Service Laboratory at Little Port Walter, Baranof Island, southeastern Alaska.

Work dealing with the assessment of genetic damage will be performed in the Genetics Laboratory at the Regional Fish and Game Office in Anchorage unless performed by Washington State University under contract.

PROJECT IMPLEMENTATION

This will be a joint project between ADFG and NMFS. ADFG will be the lead agency for overall program management and genetic damage determinations. ADFG will be responsible for field monitoring, gamete fertilization, and incubation in Components A and B. NMFS will be responsible for oil exposures, chemistries, fish culture, and hydrocarbon end points in Component C. Both agencies will have statistical analyses responsibilities, particularly with the experimental designs. Both agencies will have joint responsibilities for meshing the lab and field results to reach a conclusion in the study. ADFG and NMFS have both successfully completed their responsibilities for this project in prior years and their results have been reported in a thorough and timely manner.

The ADFG is the logical agency to conduct Components A (field monitoring) and B (evaluation of injury to gametes) of this project. They have a statutory obligation to manage Alaska's wild salmon resources and have conducted field monitoring studies of embryos and pre-emergent fry since 1961 as part of their pink and chum salmon forecasting program. They also have a long history of experimental fish culture in PWS, they have a highly qualified group of geneticists on staff in a well equipped genetics laboratory, and their biometrics staff is particularly suited to analyzing applied fisheries data.

The facilities and staff of the NMFS make this the logical agency to conduct Component C of this study. The Auke Bay Laboratory and Little Port Walter field station personnel have extensive experience with fish related hydrocarbon dose response experiments, hydrocarbon chemical analyses, and culturing salmon from embryos to mature adults. The experimental incubation system is already in place for a dose response experiment at Little Port Walter and the pen rearing set up which NMFS currently uses to rear chinook to the mature adult stage at that facility are equally well suited to pink salmon.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The foundations for this project date back to the original NRDA F/S Study 2 (Injury to Salmon Eggs and Preemergent Fry). NRDA F/S Study 2 was equivalent to the field monitoring portion of this project (Component A) and was conducted in 1989, 1990, and 1991. The same project was continued as Restoration Study R60C in 1992. Two additional elements (Components B and C) were added to Restoration Study R60C during the summer of 1992. These additions were designed to assess the genetic damage hypotheses raised through NRDA F/S Study 2. All three components were present in the 1993 project, Restoration Study 93003. This project, 95191, is the continuation of work started in Restoration Study R60C and continued in Restoration Study 93003.

Several past NRDA and present restoration projects have been and continue to be intimately related to this project. The 1989 and 1990 NRDA F/S Study 4 demonstrated reduced growth and survival for salmon which reared in oiled areas. NRDA F/S Study 1 in 1989, 1990, and 1991 and subsequent Restoration Study R60B in 1992, investigated oil damage to adult pink

salmon spawning populations and provided valuable improvements in escapement estimation procedures used by fisheries managers to monitor and protect injured wild pink salmon populations. NRDA F/S Study 3 in 1989, 1990, and 1991 and subsequent Restoration studies R60A in 1992 and 93185 in 1993 provided hatchery and wild catch contribution estimates. This information was used by fisheries managers to reduce fisheries exploitation rates on injured wild pink salmon and also provided survival estimates for groups of fish examined by NRDA Study 4. The 1989, 1990, and 1991 NRDA F/S Study 28 and a subsequent Restoration study in 1992 incorporated data from all the previous studies into life history and run reconstruction models. These models were used to extrapolate losses in adult pink salmon production from injuries observed in earlier life history stages.

The field data collection for Component A of this project is very specific to individual wild pink salmon streams and precedes or follows most field activities of the PWS Sound Ecosystem Assessment program (SEA) and other pink salmon related projects consequently extensive coordination of field activities is not feasible. However, the vessel used by this project does collect physical and biological oceanographic data for the ADFG, PWSAC, and University of Alaska Cooperative Fisheries and Oceanographic Study and these data will be utilized by several SEA studies.

The field portion of Component B includes streams that are also listed for sampling by the proposed pink salmon genetics study. Tissue samples from carcasses of fish sacrificed for eggs and sperm in these streams will be collected for genetic analyses.

Component C of this project occurs at Little Port Walter on Baranof Island in Southeast Alaska and there is little opportunity for coordination with other projects with respect to data collection.

Final edited data from all three components of this project will be stored electronically as computer databases and final versions will be provided annually to the Information Modeling portion of SEA for incorporation into a centralized ecosystem database.

FY 95 BUDGET (\$K)

Personnel	178.6
Travel	12.4
Contractual	26.6
Commodities	14.7
Equipment	4.0
Subtotal	236.3
Gen. Admin.	28.7
Total	265.0

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Injury to Salmon Eggs and Pre-emergent Fry Incubated in Oiled Gravel (Laboratory Study)

Project Number:	95191B
Restoration Category:	Research (continuation of 94191)
Proposed By:	NOAA
Cost FY 95:	\$331,000 (includes \$165,400 for data analysis and report writing on FY 94 work)
Cost FY 96:	\$133,500
Total Cost:	\$464,500
Duration:	2 years
Geographic Area:	Little Port Walter, Alaska
Injured Resource/Service:	Pink salmon

INTRODUCTION

The purpose of this study is to provide laboratory verification of the pink salmon egg mortalities from field observations presented by Sharr et al, and test the hypothesis that exposure of pink salmon eggs/alevins to an oiled incubation habitat will result in the functional sterilization of these animals at sexual maturity. This study, currently underway, utilizes controlled laboratory oil exposures to fertilized eggs in a simulated intertidal gravel environment in order to mimic environmental exposures of 1989 and 1990 (link to NRDA Study FS2). Measurements of survival, abnormalities, growth and hydrocarbon uptake will be made during exposure and rearing to sexual maturity, but the most important observation is the evaluation of gamete viability by crossing fish once they have matured.

Pink salmon were affected by the oil spill in 1989, at several life stages. Impacts to eggs, alevins, and fry were measured. With the crash of stock abundance in 1993, there was elevated concern for the long lasting effects of oil exposure, and if exposure to oil would create long lasting effects that would impact recovery. Genetic damage after oil exposures has not been observed in other oil spills, but the unique life history of intertidal spawning provides a long term oil exposure (eight months) to the developing eggs and larva. The observations of

elevated egg mortalities in oiled intertidal streams long after the spill (1990 through 1993) suggest that long lasting effects, no longer from direct oil exposure, may be occurring. The 1993 ADFG experiment that measured elevated egg mortalities from oiled streams in spawn removed to a hatchery environment (where the environment is the same for each stock) gives the long lasting effects hypotheses more credence.

This is a continuing project that was started in 1992 with the spawning of the 1992 brood year, and was repeated with the 1993 brood. This project should continue through the spawning of the 1992 brood in 1994, and the spawning of the 1993 brood in 1995, with an evaluation of the progeny viability and survival through hatch in 1996.

NEED FOR THE PROJECT

Information gained from this study will provide resource managers insight to the magnitude and persistence of damages sustained by wild pink salmon due to EVOS. Efforts to restore damaged pink salmon populations depend upon the fishery manager's abilities to identify sources of reduced survival and to monitor their persistence. Information on the potential of long term oil exposures to cause genetic damage is needed so spawning escapement goals can be reevaluated and adjusted if necessary. In addition, verification of the genetic hypothesis would provide the first evidence that reproductive capacity of fish exposed to chronic or acute sources of oil pollution would be compromised.

PROJECT DESIGN

The functional sterility hypothesis of Sharr et al. will be evaluated by crossing mature fish with known oil exposure histories. Fertilized pink salmon eggs will be incubated in oiled gravel, and the surviving fry will be reared to maturity. Mature fish exposed to oiled gravel as eggs/larvae will be crossed and the effects of oiled incubation substrate on gamete viability and offspring survival will be examined. If incubating in oiled gravel is shown to deleteriously affect gamete viability or offspring survival, then the plausibility of the functional sterility hypothesis will be established. This experiment will take place over two brood year cycles, starting in 1992 and ending in 1996 when the evaluations are completed.

A. Objectives

1. 1992 brood: Spawning of the 92 brood should occur in Sept 1994, or possibly October 1994. Adults will be examined for dose related differences in marine survival (net pens), growth, fecundity, and fertility. The spawn will be incubated in separate family groups for evaluation of survival and abnormalities through hatching.
2. 1993 brood: Juvenile fish will be cultured through the winter until sexual maturity in September or October of 1995. Dose related effects on growth, and overwinter marine survival will be evaluated.

3. Complete biological and chemical analyses of the oil exposure phases for both brood years. Integrate biological observations, chemical analyses, and contracted measurements into reports and manuscripts on the impacts through emergence.

B. Methods

This experiment began with a controlled oil exposure/gravel incubation simulation of an intertidal spawning environment. Fertilized eggs from brood years 1992 and 1993 were placed on oiled substrate and incubated to emergence. Several oil doses were utilized in both exposures. Biological responses (e.g. survival, timing of emergence, growth, size, hydrocarbon loads) to the oiled substrate were evaluated during the incubation period for both brood years, and will be updated in 1994. The surviving fry are currently being cultured to maturity and their gametes will be collected, crossed and incubated in a clean environment. Adults from the 1992 brood will mature in September 1994. Differences in gamete fertilization rates and embryo survival will be attributed to different oil exposures in the parental generation beginning in November 1994. Fish from the 1993 brood will mature in September 1995, and similar evaluations will follow.

C. Schedule

1992 Brood Year - Periods to Complete Tasks

Jul 15 - Sep 15 1992	Oil gravel, set up incubators
Sep 15 1992 - Sep 15 1993	Spawn pink salmon, and culture fry.
Sep 15, 1993	Write first interim report
Sep 15, 1993 - Sep 15 1994	Culture tagged fish in netpens spawn second generation.
Sep 15 1994	Write second interim report
Sep 15 1994 - May 15 1995	Incubate second generation,
May 15 - Aug 15 1995	Analyze and integrate data collected from culture of 1992 pink salmon and their progeny.
Sep 15 1995	Write third interim report

1993 Brood Year - Periods to Complete Tasks

Jul 15 - Sep 15 1993	Oil gravel, set up incubators
Sep 15 1993 - Sep 15 1994	Spawn pink salmon, culture fry.
Sep 15, 1994	Write second interim report
Sep 15, 1994 - Sep 15 1995	Culture tagged fish in netpens spawn second generation.
Sep 15 1995	Write third interim report
Sep 15 1995 - May 15 1996	Incubate second generation.
May 15 - Aug 15 1996	Analyze and integrate data collected from culture of 1993 pink salmon and their progeny.
Aug 15 - Sep 15 1996	Write final report

D. Technical Support

NMFS Auke Bay Laboratory will provide all laboratory facilities for fish culture, hydrocarbon

analyses, and computer facilities for data analysis and management. Histopathology and MFO contracts were let on the 1992 brood samples. ADFG genetics staff are conducting the genetics analyses (aberrations) on the lab samples provided by us and on the PWS field samples provided by the field component of ADFG. ADFG statisticians/biologists have been involved in the design and implementation of the crosses.

E. Location

Project will take place at Little Port Walter, located on Baranof Island in southeastern Alaska, using nearby intertidal stocks.

PROJECT IMPLEMENTATION

This project is currently underway at the NMFS research facility at Little Port Walter, and is managed by Auke Bay Lab.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is a component of Restoration Study 94191, a cooperative project between NMFS and ADFG. Previously implemented contracts have involved the University of California, Davis and the Woods Hole Oceanographic Institute.

FY 95 BUDGET (\$K)

Personnel	213.7
Travel	32.5
Contractual	0.0
Commodities	45.7
Equipment	7.0
Subtotal	298.9
Gen. Admin.	32.1
Total	331.0

Harbor Seal and Sea Otter Cooperative Population and Harvest Assessment

Project Number:	95244
Restoration Category:	General Restoration (continuation of 94244)
Proposed By:	ADFG
Cost FY 95:	\$89,900
Cost FY 96:	\$22,100
Total Cost:	\$112,000
Duration:	2 years
Geographic Area:	Prince William Sound and Lower Kenai Peninsula
Injured Resource/Service:	Subsistence

INTRODUCTION

The goal of the project is to work cooperatively with subsistence hunters to assess the impact of subsistence harvests of harbor seals and sea otters, and other factors, on the recovery of these species, and to identify ways to reduce these impacts. This project began in FY 94 (Project Number 94244). The work plan for FY 94 called for a summary of subsistence harvest data, collection of traditional knowledge about these populations, and compilation of biological data. To reach the project goals described in the FY 94 restoration work plan, we propose to continue this project into FY 95 to 1) complete compilation all of the available information; 2) gather additional data as needed; 3) analyze and interpret the data, in cooperation with the appropriate agencies and native groups; and 4) if necessary, produce a set of recommendations regarding harbor seal and sea otter harvesting to guide subsistence users who want to voluntarily change their harvesting practices to help these two species recover. Added to the set of objectives is an informational program, either in a slide or video format, that can be used to inform the public, including subsistence users, about the current status and trends in harbor seal and sea otter populations.

NEED FOR THE PROJECT

The populations of harbor seals and sea otters in Prince William Sound and adjacent waters were injured as a result of the *Exxon Valdez* oil spill. The U. S. Fish and Wildlife Service estimates that between 3,500 and 5,500 sea otters were killed by oil in the first months after the spill, and sea otters were still being injured by oil in the environment three years later. The

case for a population level oil spill injury to harbor seals is less clear. Harbor seal populations throughout the Gulf of Alaska are known to have been in decline before the oil spill. This decline has continued, but it is difficult to determine how much, if any; of it is due to the effects of oil in the environment. However, it is known that harbor seals were exposed to *Exxon Valdez* crude oil in Prince William Sound. They suffered some direct mortality although the number of harbor seals killed is unknown. Harbor seals also suffered sub-lethal effects, including corneal damage, nerve damage, and brain lesions.

Many subsistence hunters within the spill area, concerned about the decline they have observed in the numbers of harbor seals and sea otters, have voluntarily reduced their take of these species in an effort to help their recovery. However, at present, there is no mechanism in place to evaluate the effectiveness of these efforts.

Some data are available on marine mammal harvests in the spill area and are being summarized for the first year of the project. The Division of Subsistence, Alaska Department of Fish and Game has collected information on the numbers of harbor seals and sea otters harvested by subsistence users living in several communities in the spill region for both pre-and post-spill years. In 1993, the Division of Subsistence, in cooperation with the National Marine Fisheries Service and Ruralcap, also undertook a project to collect more detailed information on the timing and composition of subsistence harvests of harbor seals and sea lions (but not sea otters), including figures for those animals struck and lost. This project will continue into FY 95. The U.S. Fish and Wildlife Service runs a sea otter tagging program, which gathers information on sea otter harvests, including the location where animals are taken.

There is also some information available on harbor seal and sea otter populations in the region. The Division of Wildlife Conservation, Alaska Department of Fish and Game, working with the National Marine Fisheries Service has conducted a count of harbor seals in both the oiled and unoled areas of Prince William Sound, along with other research aimed at assessing the health of the harbor seals (restoration project number 93046). The U.S. Fish and Wildlife Service has continued to monitor the recovery of sea otters in oiled areas, by determining their abundance, distribution and mortality (restoration project number 93043).

This project constitutes a step towards involving subsistence hunters in the resource management process, and may lead to an on-going exchange of information and consensus building with regard to the management of harbor seals.

PROJECT DESCRIPTION

A. Objectives

Project objectives include: a compilation of available data on harbor seal and sea otter populations and trends; conducting a meeting of marine mammal biologists and subsistence users to evaluate and discuss the data; production of an informational program, either in a slide format or a video, which can be used as an educational tool about harbor seal and sea otter

populations and trends; production of a set of recommendations for subsistence users of harbor seals and sea otters based upon study findings and workshop results; and harvest location data to supplement that collected in 1994.

B. Methods

The project will involve compiling information from a variety of sources. Sea otter tagging data collected by the U.S. Fish and Wildlife Service will be used to estimate both the number of sea otters taken, and the locations in which they were hunted. The Division of Subsistence is administering a survey (funded by the National Marine Fisheries Service) in the oil spill impacted communities to gather information on the numbers of harbor seals harvested, including a breakdown by life stage and sex of the animal, and an estimate of the number struck and lost. It is anticipated that this project will continue. A section will be added to the questionnaire on location of harvest for this species. Information collected by the Alaska Department of Fish and Game, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service on the biology and population characteristics of harbor seals and sea otters in the oil spill impact area will also be used. In 1994, the Division planned to enter into a cooperative agreement with the Alaska Sea Otter Commission to assist in the interpretation of the biological and population data, and the potential effects of the harvest on the health of the populations, as such interpretation is outside of our expertise.

Following the compilation and analysis of the data, an ad hoc committee would be convened to evaluate the accumulated information and make recommendations to subsistence users. Such a committee would be composed of representatives of appropriate agencies, including the Alaska Department of Fish and Game, the US Fish and Wildlife Service, and the National Oceanic and Atmospheric Administration, and native organizations, including the Alaska Sea Otter Commission, Ruralcap, the Chugach Regional Resources Commission, and the village and traditional councils of the area. Recommendations of the ad hoc group would be presented to subsistence users both in an informational newsletter, and in community meetings. Any changes to the harvest would be voluntary, as the ad hoc group would have no authority to compel any changes. Following this meeting, additional workshops in communities would occur to summarize and discuss the findings. Additional data collection for harvests taking place in late 1994 and 1995 would take place.

Ideally, the recommendations of the ad hoc group should become part of the harbor seal recovery plan.

C. Schedule

All work will be conducted in FY 95.

D. Technical Support

The project will not require any technical support as defined in the instructions for this document.

E. Location

The study area will include Prince William Sound and the lower Kenai Peninsula. Primary marine mammal hunting communities in this area include Cordova, Tatitlek, Chenega Bay, Nanwalek, Seldovia, and Port Graham. Hunters in other communities, such as Valdez and Homer, will also be included in the project.

PROGRAM IMPLEMENTATION

This project will take advantage of several existing programs, both within the Alaska Department of Fish and Game and other agencies. These other programs are described above. The Division of Subsistence will need to contract out for someone to assist in the analysis and interpretation of the biological and population data. This kind of work is outside the expertise of the staff of the Division of Subsistence, and the Division of Wildlife Conservation will not have any personnel available for this task. We would prefer to continue the co-operative agreement with the Alaska Sea Otter Commission for this service, because their ties to the Alaska Native communities and their experience with these issues will be of benefit to the project. There will also be a need for a second contract to produce the informational program.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will incorporate information on the numbers, distribution and degree of recovery of the populations of harbor seals and sea otters from restoration projects 94064 (Harbor Seal Habitat Use and Monitoring) and 94246 (Sea Otter Recovery Monitoring Project). It will also provide information on seal and sea otter harvest in Prince William Sound and the Lower Kenai Peninsula to help the marine mammal researchers to evaluate the impacts, if any of the harvest on the recovery of those populations.

FY 95 BUDGET (\$K)

Personnel	52.7
Travel	15.0
Contractual	12.0
Commodities	1.5
Equipment	0.0
Subtotal	81.2
Gen. Admin.	8.7
Total	89.9

Kenai River Sockeye Salmon Restoration

Project Number:	95255
Restoration Category:	General Restoration (continuation of 94255)
Proposed By:	ADFG
Cost FY 95:	\$645,000 (includes \$373,800 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$614,000
Total Cost:	\$1,259,000
Duration:	2 years
Geographic Area:	Upper Cook Inlet
Injured Resource/Service:	Sockeye salmon and commercial fishing

INTRODUCTION

Sockeye salmon (*Oncorhynchus nerka*) which spawn in the Kenai River system were injured by the *Exxon Valdez* oil spill (EVOS). Greatly reduced fishing time in Upper Cook Inlet (UCI) due to EVOS caused sockeye salmon spawning escapement levels in the Kenai River to exceed that desired by three times. The biological impact of EVOS on Kenai River sockeye salmon stocks may be one of the most serious documented. Data collected by NRDA Fish/Shellfish Study 27, Sockeye Salmon Overescapement, indicated greatly reduced survival of juvenile sockeye salmon during the winter-spring rearing period beginning with the 1989 parent year. The extremely high escapement may have initially produced more rearing juvenile sockeye salmon than could be supported by nursery lake productivity. In general, when rearing salmon abundance greatly exceeds lake carrying capacity, the species and size composition of prey resources are altered which affects all trophic levels. Because of such changes, juvenile sockeye growth is reduced, freshwater mortality is increased, greater proportions of fry remain in the lake for another year of rearing, and smolt condition is reduced and marine mortality is increased. Limiting sockeye salmon fry production by closely regulating the number of spawning adults may be the only way to restore the productivity of these rearing areas. Sockeye smolt outmigrations in the Kenai River were severely reduced in 1991 (1989 parent year) and continued to decline through 1993. The number of adult sockeye salmon returning from the 1989 overescapement in the Kenai River is expected to be low. Starting in 1994, a reduction of Kenai River sockeye salmon harvests may be necessary to ensure adequate escapements.

NEED FOR THE PROJECT

Sockeye salmon harvested from the mixed-stock fishery of Cook Inlet include fish from the Kenai, Kasilof, and Susitna Rivers. In order to effectively manage the harvest of EVOS-damaged stocks, Restoration Science Studies R53/R59/93012/93015/94255 were implemented in 1992 and 1993. This proposal is the continuation of those projects through fiscal 1995. These studies use Genetic Stock Identification (GSI) techniques to identify Kenai River stocks in mixtures within the Kenai River itself and within Cook Inlet marine areas. Area managers will use this information to estimate relative abundances and modify fishery management to protect the EVOS-damaged Kenai River stocks. In addition, genetic information from Kenai River stocks is critical in the planning of many restoration options currently under consideration for the Kenai River.

GSI techniques rely on genetic variation to discriminate between populations of organisms. This method has proven to be extremely effective for allocating and adjusting the harvest of fish stocks intercepted in mixed-stock fisheries such as those that occur in Cook Inlet. Once a data base has been established, GSI techniques should provide an ongoing mechanism for in-season management. This will allow managers to control the harvest of Kenai River sockeye salmon and facilitate their recovery.

A comprehensive allozyme genetic database has been developed with collections originating from over 36 populations of sockeye salmon from the Kenai, Kasilof, and Susitna drainages as well as western Cook Inlet. Significant genetic heterogeneity has been detected not only among major regions, but also within the larger drainages. Extensive numerical analyses are being conducted to evaluate the identifiable genetic units and to test the accuracy and precision of the resulting classification model. Analyses to date indicate that although many stocks can be identified with a high level of precision, the very large spawning aggregations in the mainstem of the Kenai River require additional baseline genetic information.

A pilot fishery study was conducted during 1993 using allozyme data. Stock proportions from two fishery samplings were estimated using the genetic baseline collected during the 1992 field season. In both cases the laboratory and statistical analysis were completed within 48 hours. Routine fishery monitoring in-season can begin once the GSI model has been adequately refined and evaluated.

PROJECT DESIGN

A. Objectives

The goal of this project is to restore Kenai River sockeye salmon injured by the oil spill. This will be accomplished through improved stock assessment capabilities, more accurate regulation of spawning levels, and modification of human use. The specific objectives are to:

1. Obtain baseline allozyme genetic data (during 1992-1995) from all significant spawning

stocks contributing to mixed-stock harvests of sockeye salmon in Cook Inlet.

2. Use Genetic Stock Identification (GSI) algorithms to estimate the relative proportion of Kenai River stocks within the mainstem Kenai River and in marine mixed stock fisheries of Cook Inlet. Estimates will be made from adult, smolt, and fry samples. These data will allow managers to estimate relative abundances and genetic relatedness of Kenai River stocks to aid in restoration planning and to allow managers to modify area and time of harvest.
3. Investigate the added utility of DNA-level markers to discriminate among Cook Inlet populations.
4. Provide more accurate estimates of abundance of Kenai River sockeye salmon within Cook Inlet through hydroacoustic assessment techniques.

B. Methods

Stock Identification

Over the last two years we have developed a comprehensive genetic database of sockeye salmon stocks in Cook Inlet. In 1992 we collected baseline genetic data using allozyme analyses from 28 subpopulations from Cook Inlet including the Kenai, Kasilof, and Susitna Rivers. The majority of these were resampled in 1993 along with an additional eight populations. During 1994 we will focus our efforts in two areas: 1) refining and evaluating the model, and 2) applying the resulting model to freshwater and marine mixed stock analyses.

We proposed to refine our characterization of the large spawning aggregations within the Kenai River and to complete collections for several other Cook Inlet systems inadequately sampled in the preceding years. Target sample sizes for allozyme baseline collections will be 100 individuals to adequately characterize spawning populations. We will also analyze freshwater mixed stock samples to examine the accuracy and precision of the GSI model. Approximately 200 sockeye salmon each will be collected at least twice from fishwheels operating at the Kenai River, Kasilof, and Crescent escapement enumeration sites during the summer of 1994. A composite sample with individuals from throughout Cook Inlet will be constructed and analyzed "blind" by the genetics laboratory.

The resulting GSI model will be applied to both freshwater and marine mixed stock samples. Mixed stock samples of adult sockeye salmon will be collected from selected drift fisheries openings occurring during the July fisheries (maximum of two; 1995-1996). Sample sizes will be set at 400 to minimize the confidence intervals surrounding the estimates. Fishery composition estimates will be available within 48 hours following the fishery so that management decisions can be based on the actual composition of the fisheries. In addition, mixture samples from the Kenai River of outmigrating smolts and fry will be collected during Restoration Project 94258 to determine stock composition and provide information on production and rearing dynamics. Estimation of the relative contribution of the Russian River populations will be particularly valuable, as it is possible that the Russian River will be the major stock component within the

Kenai River in future years. Results to date indicate that the Russian River stock is genetically quite distinct and can be estimated with an accuracy greater than 0.90.

Muscle, liver, heart, and eye tissue will be taken from individual fish and examined by protein electrophoresis (allozyme analysis) for discriminating gene markers. Genotypic and allelic frequency estimates will be calculated from allozyme electrophoretic data for each baseline and mixed-stock sample at every gene locus examined and will be used to identify discrete spawning populations. Stock components of mixed fishery samples will be estimated using a conditional maximum likelihood algorithm.

We have also identified mitochondrial DNA (mtDNA) polymorphisms within Cook Inlet sockeye salmon populations that potentially could further discriminate among stocks. We will continue to collect these mtDNA markers from selected Cook Inlet populations. Total genomic DNA will be extracted and amplified through PCR (polymerase chain reaction) techniques utilizing various mitochondrial primers. Restriction analyses will be conducted, and maximum likelihood simulation studies will be performed to test the additional resolution that could be provided by the DNA-level data. DNA data will be collected from the fishery samples as scientifically and logistically feasible. We also propose to continue developmental work to identify additional nuclear DNA genetic markers through the competitive bid process.

Offshore Test Fish Program

The sockeye salmon total run to UCI has been estimated early during the season by test fishing between Anchor River and Red River delta. Northward migrating sockeye salmon are captured with a drift gill net at a series of stations. Salmon are identified to species and sex, and length measurements are recorded. Estimates of total sockeye salmon return are made several times during the season by estimating expected total test fishery catch per unit of effort for the season and catchability of sockeye salmon in the test fishery. Analysis of historical data has indicated that existing sampling effort and catch has not been proportional to abundance. To assess run size more accurately, additional sampling effort will be added to the existing program.

In 1992 and 1993 hydroacoustic equipment and techniques were tested in UCI offshore waters. Results of this work indicated that hydroacoustic techniques could detect salmon and provide a population estimate for "in season" management use. However, the primary limitations identified in the study were limitations (signal/noise ratio) of the hydroacoustic gear due to rough sea conditions or shallow water in the northern portion of UCI. In 1993, 12 orthogonal transects sampled over 48 hours within Cook Inlet provided a useable estimate of adult salmon abundance. In addition to this effort the vessel and hydroacoustic gear was deployed for six days in conjunction with the existing ADFG test fish vessel at Anchor Point. Estimates of salmon abundance were correlated with test fish catches under calm weather conditions and development of a program to estimate sockeye salmon hydroacoustic targets is encouraging.

C. Schedule

Finish baseline sample collection	October, 1994
Laboratory analyses of 1994 baseline & mixture samples	October, 1994 - March, 1995
Prepare, advertise, and award contract for UCI hydroacoustic survey and DNA marker development	Jan. - April, 1995
Final report from hydroacoustic survey contractor, FY94	February, 1995
Draft status report for FY94	March, 1995
Numerical analyses of stock structure; modelling of 1994 fishery samples	March - Sept., 1995
Baseline sample collection; fry and smolt collections	March - Sept., 1995
Fishery sample collection and in-season analysis	June - July, 1995
Hydroacoustic assessment	July, 1995
Final status report for FY94	Sept., 1995
Numerical analyses of stock structure	Sept., 1995 - Feb., 1996
Final report from hydroacoustic survey and DNA contractors	Feb., 1996
Draft status report for FY95	March, 1996
Final status report for FY95	Sept., 1996

D. Technical Support

Administrative support is provided by the Administrative, Habitat, and Commercial Fisheries Development and Management Divisions staff of the Alaska Department of Fish and Game. The project leaders are fully funded with general funds from the State of Alaska. Project assistants are fully or partially funded by this project. Laboratory support is provided by the ADFG Genetics Program which includes facilities for tissue archival, allozyme analysis, PCR-based and other DNA analyses, and data analyses. These studies are integrated with ongoing studies by the Commercial Fisheries Division for efficiency in completing the objectives.

E. Location

Upper Cook Inlet, north of a line from Anchor point to the Red River Delta. Field work will be inlet wide and based out of Soldotna; lab work and a portion of the data analyses will be conducted in Anchorage.

PROJECT IMPLEMENTATION

The allozyme and mtDNA data collection and all data analyses will be conducted by the Alaska Department of Fish and Game. Continued research and development of DNA markers will be accomplished through contractors chosen through the competitive bid process (value not to exceed \$20,000).

A sole source contract is proposed (value not to exceed \$50,000) to be awarded to *BioSonics Inc.* for continuing work in UCI with hydroacoustic equipment. *BioSonics Inc.* has been awarded the contract since 1992 through competitive bid procedures. The experience gained and the recent purchase of *BioSonics Inc.* equipment for this project make them the logical contractor for the continuation of these studies.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Field efforts for this project are coordinated with Restoration Project 94258 (Kenai River Overescapement), and the collection of fry and smolt samples is organized between the two projects. DNA analyses for this project are integrated with those of projects 94320D (population genetics of pink salmon) and project 94191 (study of oil-related embryo mortalities in Prince William Sound pink salmon).

FY 95 BUDGET (\$K)

Personnel	382.4
Travel	17.3
Contractual	101.1
Commodities	58.8
Equipment	21.0
Subtotal	580.6
Gen. Admin.	64.4
Total	645.0

Sockeye Salmon Overescapement

Project Number:	95258
Restoration Category:	Monitoring (continuation of 94258)
Proposed By:	ADFG
Cooperating Agency:	DOI
Cost FY 95:	\$998,100 (includes \$337,800 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$845,300
Total Cost:	Unknown
Duration:	Studies will continue until observed effects recover to pre-spill conditions
Geographic Area:	Kodiak Island and the Kenai Peninsula
Injured Resource/Service:	Sockeye salmon and commercial fishing

INTRODUCTION

This study is a continuation of the oil spill damage assessment program initiated in 1990. The continuing program reflects modifications based on the FY93 study results. Recommendations provided by an international review team of sockeye salmon experts provided at a March 15, 1993 meeting at Vancouver, B.C. have been incorporated.

Commercial fishing for sockeye salmon in 1989 was curtailed in upper Cook Inlet, 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. In general, when rearing fish abundance greatly exceeds the lake's carrying capacity, prey resources are altered by changes in species and size composition with concomitant effects on all trophic levels. 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. This is the brood-year interaction underlying cyclic variation in the year class strength of anadromous fish.

This project continues examining the effects of large 1989 spawning escapements on the resulting progeny and associated foraging habitat 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. Beginning in 1994, Frazer Lake has been used for future comparisons of a system receiving normal escapement. Because this lake has undergone detailed study in the past and has continued funding from other sources, minimal funding is necessary to provide for data collection to insure comparisons with Akalura and Red lakes. Similarly, Tustumena Lake on the Kenai Peninsula received normal escapements and is used as a control for the Kenai River systems. This lake differs primarily in the increased natural turbidity levels and a history of modest stocking of sockeye salmon fry.

Schmidt and Tarbox report the results through 1992 on these ongoing investigations. In addition, the study proposal reflects results of data collected in the spring of 1993. These studies suggest continued poor smolt production from the Kenai River, despite normal smolt production from Tustumena Lake, the control for this system. The 1992 and 1993 (preliminary) data indicate Red Lake zooplankton communities and nutrient levels have recovered to the level measured in 1986, prior to the oil spill. Smolt numbers appear to be lagging but adult forecasts for returns in 1994 suggest escapement goals will be met; therefore, management actions will be used as the primary method for restoration. Smolt numbers will be used to forecast future returns and provide assistance to managers in future harvest management decisions. Akalura Lake demonstrated poor zooplankton densities with low smolt numbers. The 1994 adult run is not expected to meet escapement requirements. A restoration plan for Akalura lake will be produced during the winter of 1993-94 based on analysis of data collected to date.

The 1993 smolting information from the Kenai system lakes indicate poor smolt production. In addition, the Russian River smolt project indicated very poor production, suggesting this system may also be below production expectations. This system was first identified as having suspect

production when the 1992 smolt count from the lower Kenai failed to produce sufficient numbers of age two smolt to account for historic Russian River smolt migrations. This project suggests further investigations into the Russian River are warranted.

NEED FOR THE PROJECT

The proposed studies will provide the needed data to determine the most appropriate action for recovery of these ecosystems. The monitoring of fry and smolt from the systems provide a response variable by which natural recovery through return to normal escapements can be monitored. The nutrient status, water chemistry, physical data, and the temporal and spatial distribution of the zooplankton community provide the necessary data to determine the effects of natural climatic variation, as well as response to changes in sockeye salmon densities. These data are essential to determine the type of future activities that may be required to restore the system. A pilot research/restoration project is proposed separately to examine the feasibility of more interventive types of restoration. The recent workshop on the development of restoration strategies found that this research and monitoring effort received a high priority.

PROJECT DESIGN

The studies are located on Kodiak Island and the Kenai Peninsula. Recent findings have suggested major economic damage to commercial, subsistence, and sport fisheries may result because of the over-escapement event associated with the fisheries closures on the Kenai River sockeye salmon stocks caused by the 1989 oil spill. Smolt numbers emigrating from the Kenai River in the spring of 1992 and 1993 were less than one-fiftieth the numbers estimated in 1989. This suggests a likely possibility of future returns below existing escapement goals. Red River smolt numbers from the 1989 escapement on Kodiak Island are estimated to return at rates which will provide for minimal commercial harvests if average marine survival occurs.

In addition to monitoring the damage extent, the mechanism that lead to the collapse requires definition. These studies essentially follow the pattern established in the original 1990 study plan but with significant modifications to accommodate recent findings.

A. Objectives

The following objectives are altered based on input from peer reviewers of the 1992 progress report and proposed revisions to the 1994 study program.

1. Estimate critical biological attributes (number, age, size) of both resident and migrant juvenile sockeye in overescaped and normal escaped sockeye salmon nursery lakes of the Kenai Peninsula and Kodiak Island.
2. Determine effects on smolt production and subsequent adult returns caused by large escapements resulting from fishery closures after the EVOS. These effects will be inferred by studying the changes in the rearing capacity of selected nursery lakes which were either affected or unaffected by the oil spill. Data used for these inferences include:
 - a. age and growth of juveniles and smolts,
 - b. nursery area nutrient budgets and plankton populations,
 - c. seasonal, diel, and vertical distribution of zooplankton species which are the known prey of sockeye salmon in Skilak, Kenai, and Tustumena Lake; and
 - d. seasonally available zooplankton biomass in these lakes and the relationship of this biomass to ambient temperature and light.
3. Develop a pilot research project to determine experimentally the cause of the decline and potential restorative actions. ADFG in cooperation with the regional research staff of the U.S. Fish and Wildlife Service and the Refuge staff of the Kenai National Wildlife Refuge has developed a pilot research project to further define the mechanism of sockeye salmon decline and determine the feasibility of alternative restoration opportunities. This is submitted separately but depends on data obtained through these investigations.

B. Methods

From the inception, these investigations have used an ecosystem approach to determine factors limiting the recovery of the affected sockeye salmon population.

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 ADFG 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 lake systems identified, the response (abundance, growth, and freshwater age) of rearing juveniles will be studied. Because of the significance and magnitude of the findings on Red Lake, and on Skilak/Kenai lakes, these studies will continue until observed effects on growth and the limnetic community of the lake ecosystems recovers to pre-spill conditions.

The total number of juvenile sockeye in the Kenai Peninsula lakes will be estimated through hydroacoustic surveys conducted during all years up until recovery of the system is observed. Age and size information 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 and Tustumena Lake. Depending on densities of rearing juvenile sockeye salmon, 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. Additional studies of the vertical distribution of Skilak Lake sockeye will be conducted simultaneously with population estimates with an additional sampling period, for vertical sampling only, in November 1993.

Freshwater growth and age of sockeye salmon rearing juveniles from all study systems will be determined from scale and possibly otolith measurements made either by direct visual analysis of scales or using an Optical Pattern Recognition system. In cases where data are available (e.g., Kenai and Skilak Lakes and Tustumena Lake), growth of progeny from the 1989 spawning escapements will be compared with growth or size of progeny during prior years.

The total number of smolt migrating from each system will be estimated with a mark-recapture study using inclined plane traps after Kyle and King et al. 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. 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. Smolt programs consistent with those for the study lakes are continuing for Tustumena Lake.

On the Kenai River, the smolt operation will require expansion to include the Russian River. This lake system apparently now is the dominant producer of sockeye salmon smolt and is upriver from the current smolt project on the mainstem Kenai River. To determine the production of smolt from the Kenai River mainstem, estimates of smolt production from the Russian River lake system must be completed to separate normal Russian River production from the smolt production of sockeye salmon rearing in Skilak and Kenai lakes. These methods are being established to insure current projections of smolt production from the Kenai River lake systems are not an artifact of some unknown sampling bias.

In 1993 we fished one trap in the Russian River to estimate the smolt migration. We caught few fish (less than 5000) and the catch rate was 5%. In 1994, increased trap catch rates will be required to insure we are not missing fish in this clear water system.

The current length frequency data on sockeye smolts at the Kenai mainstem river smolt traps indicates that we may be missing a portion of the Russian River smolt outmigration. With the excellent genetic separation of Russian River sockeye from mainstem Kenai fish we should be able to separate these two components in the catch. This will allow for a better total smolt estimate and verification of the Russian River smolt trap data.

The smolt data for 1993 indicated that the Russian River lake systems may be experiencing similar declines in production as the mainstem Kenai River. The 1989 escapement into this system was 138,000 adults, which is far in excess of the minimum 30,000 goal. Therefore, to evaluate the current production potential and impacts of large escapements, limnological and fry hydroacoustic/tow net surveys of the Russian lakes are proposed. Techniques duplicate those used on other systems.

In the two Kenai Peninsula lakes, early spring and late fall sampling of fry will be conducted. The reason for the additional sampling period is that approximately 50% of the weight gain from fry to smolt in the Kenai River system occurs outside of the current sampling regime. If poor survival is occurring because of limitations in rearing habitat quality during this period, these data are crucial for determining the validity of fry density causing decreased over-wintering survival. Based on peer review comments, hydro-acoustic studies of fry abundance will be conducted into Fall 1994 to track and sample the juvenile fish until cold weather prevents further studies. This is based on the assumption that most of the density dependent mortality occurs in early winter.

Studies on Kodiak Island will be reduced because of recent findings. These include elimination of the smolt weir counts on Red River; relying on mark/recapture studies with smolt traps will be used to estimate smolt abundance in 1994. In 1992 the hydro-acoustic surveys were eliminated on these lakes because of interference of stickleback with the population estimates. Samples of fall fry for age, weight, and length will continue to be collected. The variation and differences in Upper Station lakes suggest this system is inadequate as a control for Red Lake and Akalura Lake. Therefore, Frazer lake will be used as a control in the future. Monitoring of this system is primarily conducted by general fund expenditures of the Alaska Department of Fish and Game. A minor modification will be made to the program to insure compatibility with the monitoring continuing on Akalaura and Red lakes. Funding from these studies will be used to augment the regular smolt monitoring program. A second inclined plane trap will be used to ensure that adequate samples are obtained for more accurately describing smolt population numbers and AWL characteristics to insure similar precision with the Red and Akalura lakes studies. The continued poor smolt production in the spring of 1993 (600,000 Red Lake, 90,000 Akalura Lake) suggest continued monitoring of these systems is warranted.

Limnological data will be collected to monitor the response of the lakes to high juvenile rearing densities and their recovery once escapement levels decline. Table 1 provides a time-line of these studies and reflects the integration with the fisheries investigations previously discussed. These data will be used to estimate carrying capacity parameters of euphotic volume, nutrient budgets (carcass enrichment), and zooplankton biomass, body-sizes, and composition shifts. Approximately six limnology surveys will be conducted at two or more stations, to determine zooplankton species abundance and body-sizes, nutrient chemistry, and phytoplankton abundance for Kenai/Skilak, Tustumena, Red, and Frazer lakes. Methods for limnological studies are detailed in Koenings et al.

In cases where seasonal data are available (i.e. 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.

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, and Akalura lakes. This will be accomplished through analysis of growth, freshwater survival (in particular over-winter survival), and freshwater age of sockeye smolt populations. 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 smolt characteristics from each of the study systems. Also, planktonic food sources will be assessed through estimation of zooplankton prey biomass and diversity of species. Some of these analyses have been completed.

Although in the Kenai River system smolt enumerations and fall fry estimates during 1991, 1992 and the spring of 1993 produced very low numbers, zooplankton biomass estimates in Skilak Lake, the major sockeye salmon producer, have not undergone similar levels of decline. Limited stomach samples evaluated recently from 1987 indicate a possible major switch in diet, further supporting limited food availability as a likely factor in the decline. Further investigation into plankton availability and growth rates following the methods of Schmidt and Tarbox will continue.

Experimental and empirical sockeye life history/production models will be used to compare salmon production by life-stage at escapement levels consistent with management goals to the 1989 escapements. These models will be refined by use of food availability data obtained through the vertical sampling studies initiated in 1992 and to be continued through 1995.

Additionally, in the case of the Kenai system, the 1989 escapement effects will be viewed independently of the effects on previous brood years with high escapement.

Consult Schmidt and Tarbox for further discussion of analyses and methods used to date in progress reports on these investigations.

C. Schedule

The timeline of the 1995 studies is outlined on Table 1. This table depicts the sampling schedule for the integrated limnological studies and fisheries studies on the Kenai Peninsula and Kodiak Island.

D. Technical Support

Administrative support is provided by the Administrative Division, Habitat Division, and Commercial Fisheries Management and Development Division staff of the Alaska Department of Fish and Game. The project leaders and their assistants are not funded by this project and are supported with general funds from the State of Alaska. Most laboratory analyses are conducted by the limnology laboratory in Soldotna. These studies are integrated with ongoing studies by the Commercial Fisheries Management and Development Division on Kodiak Island and the Kenai Peninsula. These studies have different objectives, i.e. to manage, enhance, and rehabilitate common property salmon fisheries, but use the same techniques and data collection methods. Consequently the EVOS investigations have been integrated into the normal operations of these Divisions for efficiency in completing the objectives of these studies and the general mission of these agencies.

E. Location

Study locations are on Kodiak Island and the Kenai Peninsula. Specific sampling locations are identified in Schmidt and Tarbox (1993).

PROJECT IMPLEMENTATION

The projects have been implemented in the past through the Alaska Department of Fish and Game. Considerable infrastructure was established and the programs are dovetailed into existing agency programs to insure cost effectiveness. Although continuation of the projects could be completed by any public or private organization with the proper expertise, the Trustees need to weigh the effectiveness of such a process with the disruption of the existing program.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The Alaska Department of Fish and Game has ongoing commercial fisheries research operations on the Kenai and Kasilof River, Frazer Lake, Red River, Akalura Lake, Upper Station Lake, and Afognak Lake. In addition, the Division has ongoing data collection activities from Hidden, Karluk, and Spiridon lakes relating to the limnology of these systems. These data are integrated into statewide or regional data bases that are used to directly assess the impacts of the oil spill or are used as controls to measure the response of the studies proposed in this plan, against. In addition, the area research and management biologists for the Division of Commercial Fisheries management and development, the principal limnologist, the regional limnologist, and numerous administrative and support staff are supported by general funds provided by the Alaska legislature. To date, most of the data analysis and reporting for the Sockeye Salmon Over-escapement project has been provided from State general funds. Total funding for these programs exceeds \$1 million.

The studies proposed provide for data collection and field sampling programs. As such no environmental effect will occur beyond that of traditional fisheries management data collection activities. All activities will be within existing collecting permits or Federal special use permits issued to the Department of Fish and Game for scientific data collection activities. New programs on the National Wildlife Refuge are updated through permit amendments as needed. No other permits or other coordination activities are involved.

The investigations of Kodiak and Kenai River sockeye salmon have been integrated with long term research efforts by the Alaska Department of Fish and Game on these stocks. In addition, studies by the limnology laboratory and the fisheries development staff on Kodiak Island on these systems are included in data analysis. Study design and methodology builds off of earlier efforts. Planning and permitting of research activities and future rehabilitation efforts are coordinated through the USFWS Refuge staff in Soldotna and on Kodiak Island. Consultation and planning is conducted with the newly formed National Biological Survey Fisheries Research Laboratory staff in Anchorage. Restoration strategies on the Kenai Peninsula will be developed through a review process with the regional planning teams. An ADFG review committee, including the Sport Fish Division, will be involved when adjustments of management policies, such as escapement goals, are made. In addition, study results from the Coghill Sockeye Salmon investigations in Prince William Sound are reviewed and integrated into the data analysis process for determining the response of the Kenai Peninsula ecosystem to restoration measures.

FY 95 BUDGET (\$K)

Personnel	694.7
Travel	13.3
Contractual	76.9
Commodities	63.6
Equipment	40.0
Subtotal	888.5
Gen. Admin.	109.6
Total	998.1

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Prince William Sound Shoreline Restoration

Project Number:	95266
Restoration Category:	General Restoration (continuation of 94266)
Proposed By:	Various members of the public
Lead Trustee Agency:	ADEC
Cooperating Agencies:	NOAA, DOI
FY 95 Cost:	\$1,411,100 (includes \$97,900 for sample analysis, data analysis and report writing for FY 94 field work)
FY 96 Cost:	\$68,800
Total Cost:	\$1,480,000
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harlequin ducks, black oystercatchers, juvenile otters, subsistence, recreation and tourism, and intertidal and subtidal organisms

INTRODUCTION

The 1993 and 1994 shoreline assessments (projects 93038 and 94266) resulted in the identification of beach segments where residual shoreline oil may still be influencing recovery of resources and services, but that are difficult to cost-effectively and safely restore using currently available proven technology. In addition, through project 94090, mussel beds were identified with residual, often unweathered, oil that are also difficult to cost-effectively and safely restore.

This project would allow the Alaska Department of Environmental Conservation, in cooperation with the other Trustee Agencies, to competitively solicit private sector companies to remove oil from contaminated shorelines and mussel beds that are not recovering as quickly as desirable. The use of new, innovative methods to safely and cost-effectively restore the beaches would be encouraged. This project also would fund sample analysis, data analysis and report writing for field work carried out in 1994 as part of project 94266.

This project is proposed to respond to: 1) requests from the public (especially Chenega Bay) for additional restoration work on the beaches, and 2) proposals from private sector companies that have approached the Trustee Council and ADEC with technologies and cleaning techniques to restore oiled shoreline areas that are not responding well to natural recovery. Rather than sole-source a single method, this project allows a competitive analysis of any methods that may be available.

The presence of substantial levels of petroleum hydrocarbons persisting under dense mussel beds in Prince William Sound and the Gulf of Alaska provides a continuing source for oil to enter the food chain, potentially impacting higher consumers, especially harlequin ducks, oystercatchers, juvenile otters, and humans. There is a possible link between the presence of oiled mussels and the disruption of reproduction in harlequin ducks and increased mortality in oystercatcher chicks.

The presence and removal of residual shoreline oil is important for subsistence, recreation, sediments, mussels, and intertidal and subtidal organisms. It is also relevant to harlequin ducks, sea otters, and other injured species that feed in the intertidal area. In addition, while oil itself is not an injured resource or service, it is the cause of the injuries.

NEED FOR THE PROJECT

The oil on the beaches in the spill area is disappearing through microbial degradation, photo-oxidation, mechanical abrasion and other means. The oil on most beaches is noticeably disappearing over time. There are about a dozen beaches where natural recovery is proceeding at a very slow rate. These beaches have recently been listed by EPA and ADEC as impaired under the auspices of the Clean Water Act. There are another approximately twelve beaches that are not much better. These same beaches were difficult to deal with during the cleanup. Treatment of these beaches in the past was expensive and would probably be so in the future. The difficult question that the Trustee Council needs to address is whether an expenditure of funds for treatment to accelerate recovery of these oiled beaches is an appropriate expenditure given other restoration needs.

Shoreline Oil. The results of previous shoreline assessments have demonstrated that surface oil in the spill area has become very stable and is showing little sign of degradation. The Trustee Council authorized a project in 1994 to treat some beaches with hard surface asphalt deposits. The asphalt is broken up into very small particles that are much more susceptible to degradation by microbes and photo-oxidation. That method is much less effective on the surface oil deposits that are hard on the outside and still a gooey liquid on the inside. Some of these deposits are up to 20 cm thick.

Between 1991 and 1993, subsurface oil at comparable sites in Prince William Sound decreased on average by about one half. Still, at some sites (approximately 12) there has been little reduction in subsurface oil. These sites are primarily in low energy areas so that recovery is not aided by wave action. Most of the beaches are either heavily rock armored or have large

boulders or both. The oil is often between or under large rocks. The beaches were heavily oiled by the spill and the oil is usually in the form of a gooey brown emulsification of oil and water (mousse). The worst sites still sheen. On average, the sites are approximately one quarter to one half mile long by 50 to 75 yards wide. Most of the oil is in the high-intertidal area with small amounts in the mid-intertidal area. Very little oil is in the low-intertidal area.

Contaminated Mussel Beds. Residual subsurface oil presents a harmful set of problems where mussel beds exist in low wave energy areas. Most of the cleanup effort in 1989 through 1991 avoided the protected mussel beds since mussels are an important food source for a variety of organisms including sea otters and birds. The byssal mats and the layer(s) of mussels themselves protect the oil in an anaerobic environment and retard natural weathering and cleaning. Microbial degradation proceeds very slowly in an oxygen free environment. There appears to be slow remobilization of the oil from the sediments to the mussels, which likely provides a continuing source of oil contamination in Prince William Sound. The oiled mussels continue to be a probable route of oil exposure to higher level predators such as sea otters, harlequin ducks, and black oystercatchers — resources that have not yet begun to recover from the spill. This continuing exposure is expected to significantly delay recovery from the spill in some predators, for example in harlequin ducks. Although the oiled mussel beds are relatively few in number, since they occur in protected areas and since animals and birds tend to feed in protected areas, especially during storms, it seems likely that the oiled mussel beds are a more important source of contamination to higher trophic level organisms than would initially be indicated by the number of remaining oiled mussel beds.

Approximately 70 mussel beds were surveyed this summer in Prince William Sound as a part of project 94090. About 15 are being cleaned. The primary method for cleaning contaminated mussel beds in project 94090 will be a procedure that removes and replaces the oiled sediments from under the beds with little harm to the mussels. This procedure evolved from minimally intrusive site manipulations conducted in 1992 and 1993 by NOAA. However, that method cannot be used with all of the important and contaminated mussel beds in western Prince William Sound. Another method must be found to cleanse the approximately 15 known substantially oiled beds that remain. Most of the remaining mussel beds are characterized by large rocks. Often there is no close source of replacement sediments.

Discussion with residents, especially from Chenega Bay; interviews with recreational users; and comments from the general public indicate that in some locations the remaining oil has important social and economic consequences. Chenega residents have been adamantly unsatisfied with the oiled condition of several clusters of beaches regardless of the technical difficulties involved in further treatment. Some of the Chenega-area sites contain some of the most persistence, heavy and medium oil residual concentrations found in the spill area. While these sites probably will continue to improve over a long time, this does not appear to be acceptable to the people of Chenega Bay, who hunt and fish and beachcomb in the area adjacent to their village on a day-to-day basis. They have expressed continuing interest in accelerating the improvement through treatment of some kind.

PROJECT DESIGN**A. Objectives**

1. Demonstrate safe, cost-effective methods for cleaning beaches and mussel beds of residual oil.
2. Restore 3-5 beaches or mussel beds which have unacceptable concentrations of residual oil.
3. Solicit private sector competition and innovation to provide access to safe, cost-effective technology not currently used by Trustee Agencies that could be used to restore other oiled beaches as appropriate.

B. Methods

1. Select the beaches and mussel beds proposed for restoration. Develop a description of each beach and bed. Most of this work has already been done as a part of previous shoreline assessments, ongoing conversations with Chenega Bay residents and recreation user groups, and agency scientists. However, agency scientists and Chenega Bay residents will be involved in the location decisions to ensure that the locations chosen for restoration are the most appropriate for their ecological value and value to subsistence and recreation users.
2. Develop a Request for Proposal to Solicit Private Contractors to restore the beach segments and mussel beds. Evaluation criteria must be developed for the RFP such as the importance of price, the apparent technical feasibility, the potential benefit and harm to the environment that may result from the proposed methods, the likelihood of success, and the Contractor's past performance. Development of the criteria will be done in cooperation with the other Trustee Agencies and the Chief Scientist.
3. Distribute RFP; choose Contractor; administer Contract.
4. Develop a monitoring program to determine the degree of success of oil removal and the effects on the environment. Development of the monitoring program will be done in cooperation with the other Trustee Agencies and the Chief Scientist.
5. Conduct monitoring program before and after beach treatment.
6. Write final report.

C. Schedule

November-February 1994	Develop beach segment list, RFP, evaluation criteria, and monitoring program
March 1994	Issue RFP
May 1994	Select contractor(s)
June-August 1994	Administer contract(s), monitor sites
April 1995	Draft final report

D. Technical Support

Hydrocarbon sample analysis and mussel monitoring will be conducted by NOAA's Auke Bay Laboratory. Other monitoring components will be carried out by the appropriate entities which will be determined once agreement is reached on the monitoring program.

E. Location

Prince William Sound

PROJECT IMPLEMENTATION

The major part of this project will be implemented through a competitive solicitation (RFP).

COORDINATION OF INTEGRATED RESEARCH EFFORT

This is general restoration, not a research project. Thus, coordination is for the most part field coordination with other activities in the area.

FY 95 BUDGET (\$K)

The estimated costs are based upon proposals ADEC has received in the past to restore oiled beaches using alternative methods. This budget assume 3 beaches would be treated with different methods by different contractors at a cost of \$300,000 per beach and \$200,000 for the monitoring program. The cost per beach treatment should go down if more than one beach were treated with the same method. If, in response to the RFP, the cost per beach is less, either more beaches can be treated, more methods can be tried or funds can be returned to the Trust. Some of the beaches could be mechanically treated with heavy equipment to move rocks and sediment to expose the oil as was done during the cleanup in 1990. That may or may not be cheaper on a unit basis depending upon what is received in response to the RFP. Mechanical treatment would not work well on some of the beaches which was demonstrated during the cleanup. Also, a determination would have to be made whether mechanical treatment on a given beach would do more harm than good. The cost of the monitoring program is an estimate and may be less once it is further developed by the Agencies and the Chief Scientist.

Personnel	153.6
Travel	14.1
Contractual	1166.4
Commodities	8.0
Equipment	9.5
Subtotal	1351.6
Gen. Admin.	59.5
Total	1411.1

Chenega Chinook Release Program

Project Number:	95272
Restoration Category:	General Restoration (continuation of 94272)
Proposed By:	Prince William Sound Aquaculture Corporation
Lead Trustee Agency:	ADFG
Cost FY 95:	\$47,200
Cost FY 96:	\$47,200
Total Cost:	\$94,400
Duration:	2 years
Geographic Area:	Crab Bay near the Chenega village on Evans Island in PWS
Injured Resource/Service:	Subsistence

INTRODUCTION

In June 1994, PWSAC began a chinook salmon smolt release program at Crab Bay adjacent to the village of Chenega Bay in cooperation with the Alaska Department of Fish and Game (ADFG) and the residents of Chenega Bay, to establish local salmon runs to restore damaged resources resulting from the *Exxon Valdez* oil spill in 1989. Funding for this project was provided through the EVOS Trustee Council.

The FY95 proposed Chenega chinook salmon smolt release project will continue the 50,000 smolt release program initiated in 1994. This program is planned to eventually result in a return of adult chinook salmon to Crab Bay reaching a projected 2,000 salmon.

NEED FOR THE PROJECT

This project will provide for the replacement of salmon and other marine resources damaged by the EVOS. The residents of the Chenega village and local commercial and sports fisherman will be the principle beneficiaries of this project because of their proximity to the proposed release site.

PROJECT DESIGN**A. Objectives**

1. Rear and release 50,000 Wally Noerenberg Hatchery chinook salmon smolt in Crab Bay near the Chenega village on Evans Island beginning in Spring 1994.
2. Develop a return of 2,000 adult chinook beginning in 1998. At an average of 20 pounds per returning chinook, Chenega residents can expect to harvest 40,000 pounds of salmon annually. This projection is based on current fish culture criteria including marine survivals and growth.

B. Methods

Annually, 820,000 chinook salmon eggs are taken at PWSAC's Wally Noerenberg hatchery (WNH) on Esther Island. Brood stock are harvested from among adult chinook salmon returning to the hatchery. Following incubation, hatch and outmigration from incubator trays, chinook fry are reared in raceways at WNH for one year. Prior to release, chinook smolts are transferred to saltwater net pens at the hatchery or to remote release sites for a short period of saltwater rearing.

In the spring of 1994, 50,000 chinook smolt were taken from WNH and transported via barge and fry/smolt transport tanker to Crab Bay. This operation is proposed to continue in 1995. The smolt will be released into a 350 m³ (40 ft X 40 ft X 5 ft) net pen anchored in Crab Bay. Smolts will be reared for approximately two to three weeks at the site for imprinting and additional growth prior to release. Technical support for the incubation, hatching and feeding of the smolts will be provided by PWSAC. Residents of Chenega village will be contracted, trained in smolt feeding and rearing, and paid for services.

C. Schedule

<u>Activity</u>	<u>Begin</u>	<u>Complete</u>
Rearing (smolt)	4/94	5/95
Outmigration (fry)	3/95	4/95
Install net pen	5/95	5/95
Feed and imprint smolt	5/95	6/95
Release smolts	6/95	6/95
Dismantle/Remove net pen	6/95	6/95
Eggtake	7/95	8/95
Incubation	8/95	3/96

D. Technical Support

Technical support for the project will be provided by PWSAC. Feeding at the release site will be accomplished by the residents of Chenega.

E. Location

The location for the release is in Crab Bay, located near the Chenega village on Evans Island in PWS.

PROJECT IMPLEMENTATION

PWSAC will implement the project; residents of Chenega will be contracted by PWSAC to feed the smolt rearing at Crab Bay.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is not proposed as research, but is a program directed at resource replacement.

FY 95 BUDGET (\$K)

Personnel	6.0
Travel	0.0
Contractual	37.7
Commodities	0.0
Equipment	0.0
Subtotal	43.7
Gen. Admin.	3.5
Total	47.2

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Subsistence Food Safety Testing

Project Number:	95279
Restoration Category:	General Restoration (continuation of 94279)
Proposed By:	ADFG
Cooperating Agencies:	NOAA
Cost FY 95:	\$241,600
Cost FY 96:	\$51,500
Total Cost:	\$293,100
Duration:	2 years
Geographic Area:	Prince William Sound, the Kenai Peninsula, and Kodiak Island
Injured Resource/Service:	Subsistence

INTRODUCTION

Subsistence uses of fish and other wildlife constitute a vital natural resource service that was injured by the *Exxon Valdez* oil spill. Data collected by the Alaska Department of Fish and Game's Division of Subsistence demonstrated this injury. Annual per capita subsistence harvests declined dramatically (from 4 percent to 77 percent decline compared to pre-spill averages) in ten of the communities in the path of the spill during the first year after the event. In subsequent years, levels of subsistence harvests, ranges of uses, harvest effort, and the sharing of resources have gradually increased in all of the spill area communities. Some subsistence users reported renewed confidence in traditional foods after receiving information and health advice from the Oil Spill Health Task Force. Others returned to using subsistence foods despite their misgivings because of economic and cultural reasons. Still others have traveled to unspoiled areas to harvest resources. A view persists in the communities in the oil spill area, that the natural environment has changed in ways that still pose a potential threat to their health and their way of life. This view is partly fueled by observed abnormalities in resource species, and scarcity of some resources.

We propose to continue a subsistence restoration project involving the following communities; Chenega Bay, Tatitlek, Cordova, Valdez, Nanwalek, Port Graham, Seldovia, Kenai, Seward, Larsen Bay, Karluk, Old Harbor, Akhiok, Port Lions, Ouzinkie, Kodiak City, Chignik Lake, Chignik, and Chignik Lagoon.

In 1993 and 1994 the *Exxon Valdez* Trustee Council provided funding to restore the subsistence uses of fish and wildlife damaged by the *Exxon Valdez* Oil Spill. Community meetings were held in order to identify and map the specific areas and resources of continued concern to subsistence users. Samples of those subsistence species cited in community meetings as being of continued concern were collected from harvest areas identified during the mapping, with community representatives assisting in site selection, as well as the collection of samples. The samples were analyzed for the presence of hydrocarbon contamination, at the National Oceanic and Atmospheric Administration/National Marine Fisheries laboratory in Seattle. Community representatives were transported to the lab and given a tour of the facilities. The results of the tests, along with findings from other damage assessment and restoration studies, were interpreted by the Oil Spill Health Task Force, and reported to the communities in an informational newsletter and community visits.

At this point, there is little we can learn about subsistence food safety from additional hydrocarbon testing, and barring unforeseen circumstances, we will not be doing any further testing of this kind. The remaining samples will be analyzed by NOAA this winter; NOAA will provide a report of its hydrocarbon analysis in spring 1995. The 1995 project will continue efforts to communicate information on subsistence food safety to the communities, through the Subsistence Restoration Newsletter. The Newsletter will also be used to report information on other restoration projects, putting the information into context for subsistence users. In addition we will put in place a system for getting samples of abnormal resources from subsistence users to biologists and pathologists for study, and will report the findings of the scientists to subsistence users.

This project will assist the Trustee Council in making decisions concerning restoration, enhancement or replacement of lost subsistence resources and uses.

PROJECT DESCRIPTION

The goal of the project is to restore the subsistence uses of fish and wildlife damaged by the *Exxon Valdez* Oil Spill. It is expected that by responding to the specific oil spill related concerns of subsistence users through testing of those resources, and reporting accurate health information back to the affected communities in clear, understandable language and in one on one discussions, the confidence of subsistence users in the resource can be restored. Past efforts in this direction have been partially successful.

A. Objectives

This is anticipated to be the final year of a three year project. The following dates refer to the completion of activities for fiscal year 1995. Sampling kits will be in place in the communities by January 15, 1995, and the participating scientists will have been recruited by the same date. Four issues of the Subsistence Restoration Newsletter will be produced. The last round of community meetings will take place in September 1995.

B. Methods

Community meetings will be held in eleven communities (Chenega Bay, Tatitlek, Nanwalek, Port Graham, Seward, Larsen Bay, Karluk, Old Harbor, Akhiok, Port Lions, and Ouzinkie) to identify any continued oil spill related concerns of subsistence users. Other communities may be added if such concerns are noted by Subsistence Division researchers during community visits. Those communities where no concern is indicated in either the community meetings or by other communication will be dropped from the study.

A system will be put in place whereby subsistence users can send samples of abnormal resources that they encounter to biologists and pathologists to be examined. This will involve identifying, ahead of time, scientists willing to examine different types of specimens, and how each type of specimen needs to be handled, packaged and shipped. Community residents will need to be trained to properly preserve the different types of samples for shipping. Sampling kits will be placed in each community, and an account will be set up with an air carrier to transport samples from the communities to Anchorage. The training of subsistence users and the assembling of kits will be contracted out on a competitive basis. Reporting the information from the scientists to the subsistence users will be done by the Division of Subsistence.

Communication of health advice and information on restoration projects to residents of the impacted communities would require the production of a quarterly Subsistence Division newsletter. It is important that the findings of restoration studies be integrated into this communication effort. As this information is released it is likely to cause renewed concern among subsistence harvesters. It is not always possible to anticipate the effect a technical report, or the media accounts derived from it, will have in these communities. The newsletter will serve to put this information in context for subsistence users, following an evaluation of the information by the Oil Spill Health Task Force. It will also be important to follow distribution of the newsletter with community visits. These can involve informal visits to households and/or formal meetings. The purpose will be to further the dialogue between researchers and the communities regarding study findings.

By involving subsistence users in decisions affecting mitigation, and the monitoring, enhancement and replacement of the natural resources, we can accelerate the recovery of the resources subsistence users rely upon. There is a need in these communities to actively participate in restoration of the environment. This project provides for such involvement.

The training of subsistence users to collect samples and the assembling of collection kits will be contracted out on a competitive basis. Typesetting and printing of four issues of an informational newsletter will also be contracted out. These task involve specific skills, and can be more efficiently completed by a professional.

C. Schedule

January 1995	Informational newsletter issued, community meetings
March 1995	Training complete, kits in place in communities, scientists lined up
April 1995	Informational newsletter issued
July 1995	Informational newsletter issued
August 1995	Informational newsletter issued
April 1996	Final report on fiscal year 1994 activities

Throughout the duration of the project, there will be periodic village visits as appropriate, and samples will be processed as they come in.

D. Technical Support

Technical support will be needed from biologists and pathologists with various state and federal agencies. Some have already indicated their willingness to participate in such a project.

E. Location

Field work will be conducted on Prince William Sound, the Kenai Peninsula, and Kodiak Island. The communities of Chenega Bay, Tatitlek, Nanwalek, Port Graham, Seward, Larsen Bay, Karluk, Old Harbor, Akhiok, Port Lions, and Ouzinkie will be involved. Other communities may be added if similar concerns are identified.

FY 95 BUDGET (\$K)

Personnel	130.9
Travel	21.5
Contractual	54.8
Commodities	13.3
Equipment	0.0
Subtotal	220.5
Gen. Admin.	21.1
Total	241.6

Hydrocarbon Data Analysis, Interpretation, and Database Maintenance for Restoration and NRDA Environmental Samples Associated with the *Exxon Valdez* Oil Spill

Project Number:	95290
Restoration Category:	Monitoring (continuation of 94290)
Proposed By:	NOAA
Cost FY 95:	\$163,400 (includes \$91,900 for data analysis and report writing on FY 94 work)
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	Ongoing project; data is interpreted and archived as it is received from other projects
Geographic Area:	Oil spill area
Injured Resource/Service:	Multiple resources

INTRODUCTION

The Auke Bay Laboratory (ABL) has provided data archival and interpretive services for environmental samples that have been collected and analyzed for hydrocarbons in support of the *Exxon Valdez* NRDA and restoration efforts. The samples derive from all projects, investigators, and agencies (including both State of Alaska and Federal agencies) that have collected samples for hydrocarbon analysis. The general purpose of this project is to make a large and complex hydrocarbon database available to principal investigators, resource managers, and the public by providing user friendly services. The hydrocarbon database contains sample collection and chemical analyses information from thousands of samples from 1989 to the present. Briefly the database contains:

1. Sample collection information for >41000 samples including major sample types of sediment, tissue, water, and oil.
2. Hydrocarbon analysis information for > 12000 samples; each sample analyzed has results for 73 analytes plus quality assurance data.

3. Bile and HPLC analysis for >2400 samples.
4. Data in support of NRDA and restoration projects over the period 1989-1994.

This project will provide the following:

1. Continued use and access of 1989-94 NRDA and Restoration hydrocarbon data.
2. Expansion of the hydrocarbon database with new hydrocarbon and collection information for current Restoration studies collecting samples, requiring analysis and data archival.
3. Interpretation of past and current hydrocarbon results for PI's managers, and the public.
4. Continued quality control of sample storage, hydrocarbon analyses, and data archival.

Interpretive services include hydrocarbon data interpretation to identify probable sources of hydrocarbons found, evaluation of new hydrocarbon data for evidence of systematic bias, hydrocarbon data editing according to consistent criteria and hydrocarbon data mapping to facilitate identification of temporal and geographic trends of these data. The results of these efforts provide numerical correlates that are directly related to oil, and that may be used by PI's of other Restoration projects, by other governmental agencies, and by the general public, to assess associations of observed biological effects with concentrations of *Exxon Valdez* oil. These archival and interpretive services have been provided by staff at ABL for hydrocarbon samples generated for the *Exxon Valdez* NRDA effort, who have developed automated computer methods to insure that the various criteria are consistently applied to these data, and which result in computer-generated maps of the final results. The purpose of the presently proposed project is to integrate these additional data with the *Exxon Valdez* NRDA hydrocarbon database, and to continue to provide interpretive services, thereby insuring that hydrocarbon data resulting from Restoration efforts are directly and unequivocally comparable with the existing data. These services have been used extensively by various PI's in the production of interpreted final reports and manuscripts.

NEED FOR THE PROJECT

All restoration projects that collect samples for hydrocarbon analysis need archival of collection information, sample storage, and chemical analysis. In addition, they usually need interpretation support of the chemical analysis for reports. In many cases biologists are not qualified to interpret hydrocarbon results. Many restoration projects need access to hydrocarbon results and interpretations to make resource decisions and are benefited by these services. The Trustees and public are also benefited by permanent archiving of hydrocarbon sample collection and analytical results in a database.

PROJECT DESIGN

A. Objectives

The objective of this project is to apply and extend hydrocarbon interpretation methods and data archival developed in NRDA assessments to samples analyzed for the Restoration effort, and to insure the comparability of analytical and interpretive results with those of the NRDA effort.

B. Methods

Procedures developed during the NRDA effort will be followed in this project. Incoming samples are inventoried and collection information is entered into a database located at Auke Bay, Alaska. Hydrocarbon data will be evaluated using methods described in the final reports of *Exxon Valdez* NRDA project Subtidal #8. These methods were developed specifically for *Exxon Valdez* NRDA hydrocarbon data. Data associated with hydrocarbon samples will be added to the existing *Exxon Valdez* database. Principal investigators from all projects collecting hydrocarbon samples will be assisted by this project through archival, interpretation, and mapping of their data. Data archival will include maintenance of a Rbase database with sample collection information and hydrocarbon results. This database allows inventory of hydrocarbon sample collection, and retrieval of collection and hydrocarbon results for PI and management use. Rbase will be replaced with Oracle database to allow remote access to the data as needed. Data interpretation will include examination of the data for evidence of systematic bias, which will provide the basis for an evaluation of data quality, and a probability based determination of sources of hydrocarbons found in samples. Finally, maps of specific hydrocarbon samples will be provided on request by principal investigators, government agencies, or the general public.

C. Schedule

This project is an ongoing service task and therefore has few set milestone dates. All of the methods, including computer software written specifically for these tasks, have already been developed, tested, and applied. The requested funds are entirely for continuation of these services for additional data that will be produced by Restoration projects. Data is distributed to PI's and other interested parties as requested. Final reports will be completed in April of 1995 for 1994 activities and in April 1996 for 1995 efforts.

D. Technical Support

All technical support is on site. This includes hydrocarbon analytical facilities, computer services, database management and mapping services. The facility just acquired a CDC unix computer with Oracle database software that is connected on the internet with potential access of all users.

E. Location

The project will be undertaken at the Auke Bay Laboratory in Juneau, Alaska.

PROJECT IMPLEMENTATION

There are alternative agencies that could implement the project. These include State, University and private agencies that could be contracted to manage the database and provide chemical interpretive services. However, since ABL has established procedures, expertise, and equipment, costs would be higher and time for switching of the project would have to be accounted for. There are only a few places in the country that have the chemical expertise of Auke Bay.

COORDINATION OF INTEGRATED RESEARCH EFFORT

All PIs collecting samples for hydrocarbon analysis will be given materials and training to incorporate their samples into the database. We work closely with all PIs requesting interpretive or mapping services.

FY 95 BUDGET (\$K)

Personnel	131.2
Travel	6.0
Contractual	0.0
Commodities	6.5
Equipment	0.0
Subtotal	143.7
Gen. Admin.	19.7
Total	163.4

Salmon Growth and Mortality

Project Number:	95320A
Restoration Category:	Research (continuation of 94320A)
Proposed By:	ADFG
Cost FY 95:	\$267,800 (includes \$48,700 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$267,800
Total Cost:	Unknown
Duration:	5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink salmon and commercial fishing

INTRODUCTION

This project is a component of the Prince William Sound Systems Investigation-Sound Ecosystem Assessment (SEA) program. SEA is a multi-disciplinary effort to acquire an ecosystem-level understanding of the marine and freshwater processes that interact to constrain levels of fish, and marine bird and mammal production in Prince William Sound (PWS). The natural resources damaged by the *Exxon Valdez* oil spill cannot be effectively restored without understanding ecosystem function. This is because restoration actions directed at injured species may cause unforeseen affects within the ecosystem impacting other injured species. For example, efforts to restore salmon populations may cause predators such as walleye pollock to increase in abundance leading to impacts on marine bird reproductive success. In this case, walleye pollock, a poor quality food resource for marine birds, may replace higher-quality fish species such as Pacific herring causing reduced energy intake and reproductive success in marine birds. Our understanding of ecological interactions of this kind is insufficient and must be improved to insure that restoration actions lead to expected results. The SEA program is designed to provide a level of understanding of ecosystem function sufficient for application by restoration managers.

NEED FOR THE PROJECT

Pink salmon runs to PWS failed in 1992 and 1993. These salmon run failures have drastically affected the economy of the PWS region which is largely based on the salmon resources. It is essential that we develop an understanding of the processes that are causing these events. This information is needed to develop a strategy to restore salmon runs in PWS, if possible. At the present time, it is not clear to what extent oil-spill impacts or environmental conditions may have contributed to these salmon run failures. Low returns of hatchery-produced salmon in both years indicates that the failures were likely caused by processes occurring during the juvenile lifestage. The growth and mortality rates of juvenile salmon released into PWS in 1992 suggests that a change in predation rate may have contributed to the observed run failures.

The proposed project will compare growth rates of juvenile pink salmon among years (1989-1995), track the migration of juvenile salmon in PWS, evaluate the carrying capacity of PWS for juvenile salmon and other age 0 fish, and develop techniques for estimating pink salmon mortality within the SEA study area. An evaluation of the carrying capacity of PWS is central to the restoration of salmon and herring as well as marine birds and mammals that feed on forage fish. Due to the co-dependence of these fish species on a limited food resource, restoration actions directed at any individual species will affect other species that compete with them for food. The information derived from the proposed project will be useful to restoration managers in making decisions regarding restoration actions affecting the ecological balance among fish species important to man and other apex predators.

PROJECT DESCRIPTION

The proposed project will track the migration of juvenile salmon through PWS, estimate juvenile salmon growth, contribute to carrying capacity studies, and develop techniques for estimating mortality within the SEA study area. The proposed project will provide data on diet composition of juvenile salmon, and collect samples of other juvenile fishes (sandlance, capelin, etc.) for later stomach analysis as part of the project Forage Fish Influence on Recovery of Injured Species. The data from both of these projects will be used to evaluate the carrying capacity of PWS for juvenile fishes. Information obtained from this project regarding the migratory pathway of juvenile salmon will provide the basis for the SEA study design. The proposed project will also develop techniques for estimating the mortality of pink salmon in PWS and the Gulf of Alaska. This information is needed to determine if recent run failures are caused by processes occurring within the SEA study area or outside of this region. During the past decade, five salmon hatcheries have been established within PWS. These facilities, operated by private non-profit corporations, will release approximately 500 million juvenile salmon in 1995. Approximately one million of these fish will be marked with a coded-wire tag (CWT). Recovery of these CWT fish will play a major role in tracking the migration and growth of juvenile salmon.

A. Objectives

This project will achieve the following six objectives in 1995.

1. Estimate the growth rate and condition of juvenile CWT salmon in PWS in 1995, and test for differences in growth rate among years (1989-1995).
2. Describe the migration of juvenile salmon through PWS, estimate migration rate, and provide inseason data to other SEA researchers.
3. Estimate diet composition of juvenile pink salmon in PWS in 1995, test for differences in diet composition among years (1989-1992, 1994, 1995), and collect juvenile fish stomach samples for the project Forage Fish Influence on Recovery of Injured Species.
4. Determine if the growth rate of juvenile salmon was likely limited by low food abundance in 1995.
5. Test for differences in the relationship between juvenile salmon growth and fry-to-adult survival among years (release years 1989-1994).
6. Develop techniques to estimate the mortality of juvenile pink salmon within the SEA study area.

B. Methods**Objective 1:**

Juvenile pink salmon will be collected using beach and purse seines deployed from a 6 m long aluminum skiff. Sampling will begin the first week of May and extend to the end of June. An approximately 25 m long vessel will provide logistical support to the field crew enabling them to track the juvenile salmon migration and obtain samples of fry from a large area. Juvenile salmon will be located from visual surveys of nearshore nursery habitats. A portable tube CWT detector will be used to isolate CWT juvenile salmon from untagged fish in the catch. All CWT salmon will be retained for later analysis of growth. The total number of fish in the catch will be estimated volumetrically. Water temperature at 1 m depth will be measured at all sample sites using a thermistor.

A stratified-random sampling design will be employed to estimate the growth rate of juvenile pink salmon in PWS. Strata will be established based upon recovery date (May, June), hatchery, and treatment group. Three treatment groups receiving different feeding regimes at the hatcheries will be employed: (1) an early-fed group composed of individuals released during high zooplankton abundance after 1-2 weeks of feeding in net pens, (2) a direct-release group released during high zooplankton abundance after only 2-5 days of feeding, and (3) a late-fed group released during declining zooplankton abundance and increasing temperatures after 1-2 weeks of feeding.

Coded-wire tags will be extracted and interrogated as they are recovered in the field. This will enable specific treatment groups to be targeted. Methods developed by the ADFG CWT Laboratory for extracting and interrogating CWTs will be employed. Analysis of variance (split-plot design) will be used to test for differences in growth rate among years. Recovery site will be used as the sample unit in the analysis. Condition of CWT juvenile salmon will be examined to evaluate feeding and growth conditions.

Objective 2:

Immediately after the juvenile salmon are released from the Wally H. Noerenberg (WHN) Hatchery, the sampling crew will begin surveys of nearshore habitats adjacent to the hatchery. The sampling crew will start surveying at a distance from the hatchery and move toward it until juvenile salmon are encountered. It is expected that this approach will enable detection of the leading edge of the juvenile salmon migration as the fish move away from the hatchery. CWT juvenile salmon will be recovered from selected schools to determine the origin and time of release of the fish. The migration rate of juvenile salmon will be estimated during the initial phase of the migration from recovery of CWT fish. Later in the season after the fish have dispersed, it will likely not be possible to track the leading edge of the salmon migration or estimate migration rate.

Objective 3:

Stomach contents analysis will be used to estimate diet composition of juvenile salmon, examine diet overlap among juvenile fishes, and determine if the growth rate of juvenile salmon was likely limited by low food abundance. A stratified-random sampling design will be employed to estimate diet composition of juvenile salmon. Strata will be established based upon date (May, June), area, and habitat type. Site will be used as the sample unit in the analysis. Samples of untagged juvenile pink salmon ($n=15$) will be collected between 1500 and 2100 hours from approximately 10 randomly selected sites within each strata. Whenever possible, samples of other juvenile fishes (forage fish) will be collected along with samples of juvenile salmon.

Stomach contents analysis will be conducted later in the laboratory. Prey items in the gut will be identified to the lowest possible taxonomic level and enumerated. Prey biomass in each category will be estimated by the product of prey abundance and average prey wet weight. Total stomach contents weight will be measured to an accuracy of 0.1 mg. Diet composition will be expressed as a proportion of total stomach contents weight. Stomach fullness will be expressed as a proportion of fish body weight. An analysis of variance will be conducted to test for differences between years in total stomach contents weight and biomass in each prey category after the data are rank transformed. Independent variables in the model will include date (May, June), area, and habitat type.

Objective 4:

A simple bioenergetics model will be applied to evaluate whether the growth of juvenile pink salmon was likely limited by low prey density in 1995. The model will estimate the time required for a 1 g pink salmon to obtain a maximum daily ration composed of either large or small copepods at specific temperatures and prey densities. The time required to obtain a ration composed of mixed prey will be estimated from diet composition data and model estimates of

feeding times required for large and small copepods, respectively. Feeding times in excess of available daylight will indicate that the fish may not have acquired the maximum daily ration.

Objective 5:

The relationship between juvenile growth rates and fry-to-adult survival will be evaluated from recoveries of CWT juveniles and adults. The Pink Salmon Coded-wire Tag Recovery project will provide data on survival rates of CWT pink salmon released in 1994. Analysis of covariance will test for differences in the intercept and slope of the regression model between years. Mean growth and survival rates for fish from various treatment groups (early fed, direct release, late fed) will be used in the analysis. The independent variable will be release year with mean growth rate of juvenile pink salmon in each treatment group as a covariate.

Objective 6:

A feasibility study will be conducted to develop a technique to estimate the mortality of pink salmon in PWS and the Gulf of Alaska. This critical element of the SEA program is intended to determine if year-class success is established in PWS. It is expected that a full-scale project will be initiated during the 1996 field season when otolith mass-marked pink salmon will be released from PWS hatcheries. The project will employ a technique developed by Parker. In 1996, pit tags will be applied to large juvenile pink salmon (total length > 100 mm) captured near the southwest entrances to PWS. At about 100-125 mm in length, juvenile pink salmon migrate from bays and passages into the coastal zone adjacent to the Gulf of Alaska). If possible, pink salmon of primarily hatchery origin will be tagged, because in this case recovery of tagged adults will be greatly simplified. If wild fish are tagged, the tag recovery program will need to scan wild fish in hundreds of streams in PWS - greatly increasing the cost of the program. Feasibility studies conducted in 1994 and 1995 will determine if large juvenile pink salmon of primarily hatchery origin can be captured near the southwest entrances to PWS in large numbers. In early July, a purse seine vessel will use an approximately 250 m x 20 m (11/16 " stretch mesh) purse seine to capture juvenile salmon. The vessel and gear will be provided by the Juvenile Salmon & Herring Integration component of the SEA program.

C. Schedule

The field season for this project will be from April to July of each year. Laboratory and data analysis will be conducted during the remainder of the year.

Track Migration & Growth

5/1/95 - 6/30/95 Track migration and growth

7/6/95 - 7/10/95 Sample juveniles exiting PWS

Laboratory & Data Analyses

7/1/95 - 12/31/95 Conduct stomach contents analysis

1/1/96 - 3/31/96 Analyze data and prepare annual report

D. Technical Support

Hydroacoustic assessments of juvenile salmon distribution and abundance will be provided by the Nearshore Fish component of SEA. Data archiving services will be required for this project to insure that all information is adequately documented and archived. This service will be provided by the modeling and data management component of SEA.

E. Location

This project will be conducted in PWS which has experienced failures in both wild and hatchery salmon runs in 1992 and 1993. The economic health of the communities (Whittier, Valdez, Cordova) in this region is dependent on the salmon resource. The proposed project will focus sampling effort in western PWS which is known to be a major migratory pathway for juvenile salmon exiting the Sound.

PROJECT IMPLEMENTATION

The ADFG will collect field samples of juvenile salmon for this project. The ADFG is responsible for managing the pink salmon resource in the PWS area. In addition, the ADFG is responsible for the development, oversight, and evaluation of the salmon enhancement program. The recent decline in salmon survival in PWS has jeopardized the viability of the salmon enhancement program. The ADFG has conducted field studies on juvenile salmon in PWS during the past five years. Stomach contents analyses of juvenile salmon will be conducted by the National Marine Fisheries Service, Auke Bay Laboratory (Molly Sturdevant) and the University of Alaska Fairbanks (Steve Jewitt). The proposed project will also collect samples that will be analyzed within the project Forage Fish Influence on Recovery of Injured Species.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will be highly integrated with several other components of the SEA Program as well as other projects in the FY 95 workplan. Within the Physical Oceanography component of SEA, conductivity, temperature, depth (CTD) profilers will be deployed from vessels working under Salmon Growth and Mortality. Within the Zooplankton component of SEA, zooplankton samples will be collected using nets deployed from vessels working under Salmon Growth and Mortality. Salmon Growth and Mortality will also provide fish stomach samples for the project Forage Fish Influence on Recovery of Injured Species. The Pink Salmon Coded-wire Tag Recovery Project will provide data on survival rates of pink salmon released from PWS hatcheries. This data is essential to quantify the relationship between juvenile salmon growth and fry-to-adult survival. The proposed Otolith Mass Marking Project will develop a new mass marking tool for pink salmon in PWS. Mass marking of juvenile salmon will greatly improve the feasibility of studies designed to examine interactions between wild and hatchery salmon during the early marine period. All data collected as part of Salmon Growth and Mortality will be provided to the Information and Modeling component of SEA.

FY 95 BUDGET (\$K)

Personnel	170.1
Travel	1.2
Contractual	49.8
Commodities	17.7
Equipment	0.0
Subtotal	238.8
Gen. Admin.	29.0
Total	267.8

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Prince William Sound Pink Salmon Genetics

Project Number:	95320D
Restoration Category:	General Restoration (continuation of 94320D)
Proposed By:	ADFG
Cost FY 95:	\$227,000 (includes \$56,500 for data analysis and report writing on FY 94 work)
Cost FY 96:	\$133,100
Total Cost:	\$360,100
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink salmon and commercial fishing

INTRODUCTION

Historically, approximately five-hundred-million wild pink salmon fry emerged from streams throughout Prince William Sound (PWS) each year to migrate seaward. Adult returns of wild pink salmon averaged from 10 to 15 million fish annually. Unlike returns of adult hatchery fish, these returning wild-stock adults play a critical role in the total Prince William Sound ecosystem; they convey essential nutrients and minerals from the marine ecosystem to estuaries, freshwater streams, and terrestrial ecosystems. Both juveniles and adults are important sources of food for many fish, birds, and mammals. Wild pink salmon also play a major role in the economy of PWS because of their contribution to commercial, sport, and subsistence fisheries in the area.

Wild-stock pink salmon suffered both direct lethal and sublethal injuries as a result of the *Exxon Valdez* oil spill (EVOS). Pink salmon embryos and alevins suffered increased mortality, diminished growth, and a high incidence of somatic cellular abnormalities as a result of spawning ground contamination and rearing in oiled areas. Elevated mortality of embryos in the oiled streams has continued through 1993, raising the specter of petro-chemical induced genetic damage. Also, in 1989 the commercial harvest of pink salmon had to be shifted away from the hatchery and wild stocks in the oiled areas to target only the wild stocks in eastern Prince William Sound. This resulted in over-harvest and depletion of these stocks evidenced by general run failures of eastern-sound stocks in 1991. Wild-stock run failures in the Southwest area of the Sound have continued through the 1992 and 1993 fishing seasons.

Prince William Sound is the center of one of the State of Alaska's largest aquacultural industries. Alaska Department of Fish and Game has admittedly been grappling with management of the wild stocks in face of intractable hatchery/wild-stock interactions for nearly a decade. The EVOS-related damages to wild stocks, coupled with full-scale hatchery egg takes, has exacerbated wild-stock management concerns. The commercial fishing industry and the regional aquaculture association are facing serious financial challenges due to the alterations in management imposed resulting from declines in abundance of wild pink salmon stocks.

NEED FOR THE PROJECT

Understanding genetic structure of the wild stocks inhabiting PWS is critical to their management and conservation. For example, managing on too fine a scale may adversely affect the fishing industry and waste management resources, while managing on too large a scale may result in loss of genetic adaptations and diversity in the wild pink salmon populations within Prince William Sound. Knowledge gained through this project is needed to correctly interpret and apply the findings obtained from the proposed ecosystem analyses on a population basis, more properly define the population-level nature of the damage documented in previous study of EVOS damaged pink salmon, and otherwise guide the decision-making process in the management-oriented restoration of the EVOS-damaged pink salmon populations.

PROJECT DESIGN

A. Objectives

1. Define the genetic structure of pink salmon stocks in the EVOS-affected area in order to better direct harvest management decisions made for restoration purposes on a stock-specific rather than species-specific basis.
2. Provide information needed for genetic risk assessment and genetic monitoring of supplementation programs (e.g., as a result of Restoration Science Project R105) to guide stock-specific restoration and enhancement.

B. Methods

Tissues for baseline genetic data will be collected from up to 100 individuals from each of 30 spawning aggregations each year. This will include two hatcheries and 28 wild-stock streams in the affected areas of Prince William Sound. Pink salmon have a two-year life cycle. Even and odd-year pink salmon are genetically distinct, so both must be sampled. Sampling will be designed to include both early and late stocks and inter-tidal and upstream-spawning stocks. Tissue samples from heart, liver, muscle, and aqueous humor from each individual will be immediately frozen on liquid nitrogen and returned to Anchorage for storage at -80° C.

Sampling will be done in coordination with other restoration programs in order to reduce costs and facilitate cross-referencing of biological data. For example, suitable samples from odd-year stocks are already available from tissue collections made as a part of other studies. Samples for even-year stocks would be collected as a part of Restoration Science Study 94192.

Genetic data will be collected using the techniques of allozyme electrophoresis on all samples. A pre-oil spill data base of allozyme frequencies exists for Prince William Sound pink salmon which facilitates analyses of potential changes of population structure and gene flow. A pilot study using DNA techniques will be conducted on a subset of samples. ADFG anticipates contracting the laboratory analyses of the allozyme portion of the study to a qualified bidder. Data analyses will be conducted by ADFG, and data will be merged into the state and federal inter-agency databases.

C. Schedule

Activity	Inclusive Dates	
Advertise and award contract for allozyme analyses	June 1994	August 1994
Lab analyses (odd-year samples)	August 1994	April 1995
Data analyses	December 1994	June 1995
Additional field collections	July 1994	August 1994
Draft status report FY 94	March 1995	
Final status report FY 94	August 1995	
Lab analyses (even year)	March 1995	February 1996
Data analyses	September 1995	May 1996
Draft status report FY 95	May 1996	
Final report	September 1996	

D. Technical Support

Administrative support is provided by the Administrative, Habitat, and Commercial Fisheries Development and Management Divisions staff of the Alaska Department of Fish and Game. The project leader is fully funded with general funds from the State of Alaska. Project assistants are fully or partially funded by this project. Laboratory support is provided by the ADFG Genetics Program which includes facilities for tissue archival, allozyme analysis, PCR-based and other DNA analyses, and data analyses. These studies are integrated with ongoing

studies by the Commercial Fisheries Division for efficiency in completing the objectives.

E. Location

The field portion of this project will be conducted in Prince William Sound (based out of Cordova), and the data analyses will be completed in Anchorage. The project outcome will influence the long-term viabilities of wild stocks in Prince William Sound which will in turn affect the economies of the fishing communities therein.

PROJECT IMPLEMENTATION

The research direction, DNA pilot study, and data analysis will be done at the Alaska Department of Fish and Game Genetics Laboratory. We have extensive experience with genetic stock identification projects, we conducted the pre-oil spill genetic analysis of area populations, and we have developed software to handle acquisition, management, and analysis of large data sets.

The allozyme analysis portion of this project will be contracted to a qualified bidder following the state bidding process. The allozyme portion will not be done in-house in order to optimize use of Department staff and facilities on projects in progress (such as the genetic analysis of Cook Inlet sockeye salmon, EVOS study 94255).

We have already implemented a screen for mtDNA variation on six populations using an analysis of restriction fragment length polymorphisms. Data from 16 restriction endonucleases confirm earlier allozyme results that showed that even- and odd-year pink salmon have discrete population structure. These preliminary results also suggest structure separating eastern and western Prince William Sound populations.

Sample collection for fiscal year 1995 will be accomplished by ADFG staff from the Cordova office. Funds for the necessary air charter were originally a part of the budget of one of the Cordova-based projects that was deferred by the *Exxon Valdez* trustee council. This project budget includes \$30,000 to replace those costs.

COORDINATION OF INTEGRATED RESEARCH EFFORT

Some sample collections were opportunistically conducted by personnel working on pink salmon egg/fry survival projects during 1991 and 1992. Additional sample collections in 1994 will be integrated between 94191 (oil-related embryo mortalities) and this project in order to most efficiently utilize resources. Collections will represent populations of concern identified in part by coded-wire-tag project 94184.

DNA analyses for this project are integrated with those of Trustee Council projects 94255 (Kenai River sockeye salmon) and project 94191.

No funds are requested for biometrics support of this project. Biometrics will be integrated into the responsibilities of the genetics staff biometrician who is primarily funded from general funds and partially funded from project 94255.

FY 95 BUDGET (\$K)

Personnel	49.8
Travel	5.0
Contractual	140.0
Commodities	15.0
Equipment	0.0
Subtotal	209.8
Gen. Admin.	17.2
Total	227.0

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Juvenile Salmon and Herring Integration

Project Number:	95320E
Restoration Category:	Research (continuation of 94320E)
Proposed By:	ADFG
Cost FY 95:	\$943,100 (includes \$98,000 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$927,100
Total Cost:	Unknown
Duration:	4 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring, pink salmon, commercial fishing

INTRODUCTION

This project is a component of the Prince William Sound Systems Investigation-Sound Ecosystem Assessment (SEA) program. SEA is a multi-disciplinary effort to acquire an ecosystem-level understanding of the marine and freshwater processes that interact to constrain levels of fish, and marine bird and mammal production in Prince William Sound (PWS). The natural resources damaged by the *Exxon Valdez* oil spill cannot be effectively restored without understanding ecosystem function. This is because restoration actions directed at injured species may cause unforeseen affects within the ecosystem impacting other injured species. For example, efforts to restore salmon populations may cause predators such as walleye pollock to increase in abundance leading to impacts on marine bird reproductive success. In this case, walleye pollock, a poor quality food resource for marine birds, may replace higher-quality fish species such as Pacific herring causing reduced energy intake and reproductive success in marine birds. Our understanding of ecological interactions of this kind is insufficient and must be improved to insure that restoration actions lead to expected results. The SEA program is designed to provide a level of understanding of ecosystem function sufficient for application by restoration managers.

The proposed project is a continuation of the Salmon Predation component of the SEA program. The name of the project has been changed to reflect the level of integration between this project and the other components of SEA, as well as the greater emphasis placed on collection of juvenile herring samples in FY95. The primary purpose of this project is to determine to what extent variations in predation affect the survival of juvenile pink salmon, and identify and describe the mechanisms that cause variations in predation. The project will also collect samples for the following projects: (1) Juvenile Herring Growth and Habitat Partitioning and (2) Forage Fish Influence on Recovery of Injured Species. Vessel charters for all shared research platforms, including the critical Physical Oceanography and Zooplankton components of SEA, are also included in this project.

NEED FOR THE PROJECT

The pink salmon (*Oncorhynchus gorbuscha*) return to PWS failed in 1992 and 1993, and the Pacific herring (*Clupea harengus pallasii*) population collapsed in 1993. The economic survival of the communities in the PWS region is dependent on restoration of these fishery resources. At the present time, it is not clear to what extent oil-spill impacts or environmental conditions may have contributed to these run failures. The SEA program will investigate ecological processes that may have contributed to the loss of salmon and herring populations and that will affect their restoration. The Salmon and Herring Integration component of SEA will examine predation on juvenile salmon and collect fish samples for several other restoration projects. Low returns of hatchery-produced salmon in 1992 and 1993 indicates that the salmon run failures were likely caused by processes occurring during the juvenile lifestage. The growth and mortality rates of juvenile salmon released into PWS in 1992 suggests that a change in predation rate may have contributed to the observed run failures. The ecological processes that may have caused the collapse of these fish populations must be understood to identify appropriate restoration actions. Important fish predator species may include adult pink salmon and herring, walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and dolly varden trout (*Salvelinus malma*).

Additionally, since this project provides platforms and sample collection for several core SEA projects, it is critical to the overall success of the SEA program.

PROJECT DESIGN

This is a multi-year project designed to test two hypotheses regarding mechanisms that may regulate predation on juvenile salmon and herring (and other age-0 fish) in PWS. Regulation of prey population size by a predator requires that prey mortality rate increase with prey population size (i.e density-dependent mortality. Intense predation immediately after ocean entry may have contributed to poor survival of relatively large release groups of hatchery-reared coho salmon. Learned behavior or response to environmental cues may cause predators to aggregate in areas where prey are consistently abundant. Alternatively, predation on a prey population may increase when the preferred prey of potential predators is not available. In the

northern Gulf of Alaska, predators such as juvenile walleye pollock that prefer macrozooplankton may switch to age-0 fish when macrozooplankton abundance is low. Macrozooplankton abundance was very low in PWS in 1992 indicating that predators may have switched to juvenile salmon. The following hypotheses will be tested by the project: (1) The predation rate (mortality rate) on juvenile salmon is greater when juvenile salmon abundance is high. (2) The predation rate on juvenile salmon is greater when macrozooplankton abundance is low.

A. Objectives

1. Estimate the juvenile salmon consumption rate of fish predators in Prince William Sound.
2. Determine the relationship between juvenile salmon predation rate and macrozooplankton abundance.
3. Determine the relationship between juvenile salmon predation rate and juvenile salmon abundance.
4. Collect samples for the following projects (1) Herring Growth and Habitat Partitioning and (2) Forage Fish Influence on Recovery of Injured Species.
5. Provide shared sampling platforms for the SEA Program.

B. Methods

Objective 1

Fish biomass, food consumption rate (daily ration), and diet composition must be estimated for each potential predator species to estimate juvenile salmon consumption rate. The Nearshore Fish component of the SEA program will estimate fish biomass using hydroacoustic techniques. The Juvenile Salmon & Herring Integration component of SEA will estimate predator species and size composition, food consumption rate, and diet composition.

Field studies will be initiated on April 20 and continue until July 22. Approximately 180 million juvenile salmon will be released from the Wally H. Noerenberg (WHN) Hatchery beginning in late April through late May. The high abundance of juvenile salmon near the hatchery will increase the likelihood of encountering salmon in predator stomachs. Estimates of juvenile salmon consumption rate will be made for six ten-day sampling periods in two study areas in northwest and southwest PWS. The first four surveys will be conducted in northwest PWS prior to June 15 when juvenile salmon released from the WHN Hatchery will likely be abundant in the area. The last two surveys will be conducted in southwest PWS prior to July 22 when juvenile salmon from all hatcheries in PWS will likely be abundant in the area. Three vessels will be employed to sample salmon predators during predation rate surveys. An approximately 25 m trawl vessel will sample fish in offshore areas using a 40 m x 28 m mid-water wing trawl equipped with a net sounder. Two purse seine vessels will sample salmon predators in

nearshore areas using small-mesh seines. A stratified random sampling program will be employed to minimize the variance estimate of predator biomass and the proportion of predator stomach contents weight comprised of juvenile salmon. As a result, strata will be established based upon the abundance of predators and juvenile salmon in the study area. The daily ration of salmon predators will be estimated from diel feeding periodicity studies conducted once during each ten-day sampling period.

Objective 2

Multiple regression analysis will be used to provide an assessment of the macrozooplankton-dependent predation hypothesis. Juvenile salmon predation rate will be used as the dependent variable in the model with macrozooplankton abundance (from the Zooplankton component) as the independent variable. Data from paired predator stomach and macrozooplankton samples will be used in the analysis.

Objective 3

Multiple regression analysis will be used to provide an assessment of the density-dependent predation hypothesis. Juvenile salmon predation rate will be used as the dependent variable in the model with juvenile salmon abundance (from the Nearshore Fish component) as the independent variable. Paired estimates of juvenile salmon density (hydroacoustic) and juvenile salmon predation rate will be used in the analysis.

Objective 4

Fish samples will be collected for two proposed FY95 projects: (1) Herring Growth and Habitat Partitioning, and (2) Forage Fish Influence on Recovery of Injured Species. Samples of juvenile herring will be collected in nearshore and offshore habitats in passages in PWS. Data files will be provided to the Herring Growth and Habitat Partitioning project detailing the distribution, size, and age of herring collected in the study area. Fish samples will be provided to the Forage Fish Influence on Recovery of Injured Species project for analysis of stomach contents.

Objective 5

Two vessels will be chartered to provide shared sampling platforms for the SEA program. A mid-water trawl vessel will conduct mid-water trawling, CTD sampling, vertical plankton net sampling, and hydroacoustic surveys for fish. A smaller vessel will accompany the trawler to provide a platform for ADCP, OPC, Tucker Trawl sampling, and high frequency hydroacoustic sampling.

C. Schedule

The field season for this project will be from March to July of each year. Laboratory and data analysis will be conducted during the remainder of the year.

Predation Rate Surveys

April 20 - April 30

May 1 - May 11

May 20 - May 30

June 1 - June 11

June 19 - June 31

July 6 - July 18

Northwest PWS Survey

Northwest PWS Survey

Northwest PWS Survey

Northwest PWS Survey

Southwest PWS Survey

Southwest PWS Survey

Laboratory & Data Analyses

June 1 95 - Dec 31 95

Conduct stomach contents analysis and read otoliths

Jan 1 96 - Mar 31 96

Analyze data and prepare annual report

D. Technical Support

Hydroacoustic estimates of predator abundance, biomass, and size composition will be provided by the Nearshore Fish component of SEA. Data archiving services will be required for this project to insure that all information is adequately documented and archived. This service will be provided by the modeling and data management component of SEA.

E. Location

This project will be conducted in PWS which has experienced failures in both wild and hatchery salmon runs in 1992 and 1993. The economy in the PWS region is based upon these salmon resources. The economic health of the communities (Whittier, Valdez, Cordova) in this region is dependent on the salmon resource. During the first year of study, the project will focus sampling effort in western PWS which is known to be a major migratory pathway for juvenile salmon exiting the Sound.

PROJECT IMPLEMENTATION

The ADFG will conduct field sampling and laboratory processing of fish predators collected by this project. The ADFG is responsible for managing the pink salmon resource in the PWS area. In addition, the ADFG is responsible for the development, oversight, and evaluation of the salmon enhancement program. The recent decline in salmon survival in PWS has jeopardized the viability of the salmon enhancement program. The ADFG has conducted field studies on juvenile salmon in PWS during the past five years. This project will collect samples that will be analyzed within two additional projects (1) Herring Growth and Habitat Partitioning and (2) Forage Fish Influence on Recovery of Injured Species. Sample and data analysis in these projects will be contracted to the University of Alaska.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project will be highly integrated with several other components of the SEA Program. The Physical Oceanography, Nearshore Fish, Zooplankton, and Phytoplankton components of SEA will share research platforms with the Juvenile Salmon and Herring Trophics and SEA Vessel Support. Within the Physical Oceanography component of SEA, conductivity, temperature, depth (CTD) profilers and Acoustic Doppler Current Profilers (ADCP) will be deployed from the mid-water trawl vessel that will be chartered as a part of Salmon Predation. Within the Nearshore Fish component of SEA, hydroacoustic gear will be deployed from the mid-water trawl vessel and a dry lab will be provided on the vessel for a hydroacoustic technician. Within the Zooplankton and Phytoplankton components, zooplankton and water samples will be collected using nets and water bottles from the mid-water trawl vessel. Each of the two seine vessels chartered by Salmon Predation will provide logistical support (bunks, meals, etc.) for an associated small hydroacoustic boat. The hydroacoustic technician will be responsible for CTD deployment. Fishery biologists on each seine vessel will collect zooplankton samples for the Zooplankton component. Salmon Predation will also collect age-weight-length data from forage fish and provide stomach samples for the Forage Fish Project. The Pink Salmon Coded-wire Tag Recovery Project will provide data on survival rates of pink salmon released from PWS hatcheries. This data is essential to quantify the effect of predation on juvenile salmon survival rates. The Otolith Mass Marking Project will develop a new mass marking tool for pink salmon in PWS. Mass marking of juvenile salmon will greatly improve the feasibility of studies designed to examine interactions between wild and hatchery salmon during the early marine period and later during spawning. All data collected as part of the Juvenile Salmon & Herring Integration project will be provided to the Information and Modeling component of SEA.

FY 95 BUDGET (\$K)

Personnel	374.9
Travel	2.8
Contractual	374.4
Commodities	97.0
Equipment	17.8
Subtotal	866.9
Gen. Admin.	76.2
Total	943.1

SEA Plankton Dynamics: Phytoplankton and Nutrients

Project Number:	94320G
Restoration Category:	Research (continuation of 94320G)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cooperating Agencies:	NOAA
Cost FY 95:	\$239,300 (includes \$88,500 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$283,400
Total Cost:	\$522,700
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

The Sound Ecosystem Assessment program (SEA) targets the restoration of recruitment success of pink salmon and herring from the perspective of ecosystem process controls. Specifically, the SEA hypothesis is that restoration of fish stocks is regulated by the physical forces on the circulation of Prince William Sound, which alternates between years of strong through-flow, river-like conditions, and relatively stagnant, lake-like conditions. The ecological consequence of these alternate conditions is a high biomass of large zooplankton in lake years that becomes the primary nourishment for target fish and their predators (this has been termed the "middle-out" food web control). In alternate river years, the large zooplankton are sparse and predation on the target species predominates (the "top-down" control).

While middle-out/top-down is the principal hypothesis being tested by SEA research, ecological theory provides another possibility, that of "bottom-up" control, where the restoration of populations of upper trophic level species is modulated by variations in nutrient-driven phytoplankton production. In this hypothesis the structure and composition of the zooplankton community can be determined by variations in phytoplankton primary production and by the species composition of the phytoplankton community. For example, a phytoplankton population dominated by large diatoms may support an abundance of large oceanic copepods, whereas a

phytoplankton population dominated by smaller flagellates may result in a reduced number of larger copepods, or in a shift to a zooplankton community dominated by smaller neritic copepod species. Variations in the timing of phytoplankton populations have been previously suggested to be a control of ecosystem events in Prince William Sound). In this component, we will provide the nutrient and phytoplankton data that are essential to evaluate the influence of phytoplankton dynamics on the food web and test the role of the bottom-up hypothesis in ecosystem restoration.

A central tenet of the SEA hypothesis is the variable advection of Gulf of Alaska waters into Prince William Sound. Advection affects not only zooplankton populations, but also the Prince William Sound phytoplankton populations and production. Strong advection may confound the effects of in situ primary production in the Sound. To further test the hypotheses and evaluate the overall ecosystem restoration, we propose to use satellite-derived sea-surface temperatures to monitor the movement of Gulf of Alaska surface waters into Prince William Sound and, after September 1994, to use satellite-measured surface chlorophyll concentrations to determine the effect of advection on the observed chlorophyll field. We will also take over the moored instrument array (C-LAB) that has been gathering continuous relevant data for the past two years.

PROJECT DESCRIPTION

All components of the marine ecosystem study will benefit from this project. Primary production is the basis of the food web, hence any evaluation of restoration must consider the phytoplankton community and its production. In a general way, all subsequent energy transfers are ultimately based on the phytoplankton production in the sound or the phytoplankton biomass imported in the oceanic waters by advection. Many species in PWS have suffered declines in recent years. In particular, the pink salmon and herring populations in the sound have been damaged and are not recovering in a predictable manner. Also harbor seals, predators of these and other fishes, are continuing to decline. While many ideas have been proffered about the causes of mortality and/or low production, food cannot be ruled out, and hence phytoplankton production is directly or indirectly implicated in restoration and maintenance of the ecosystem. Surprisingly, there has been almost no work on phytoplankton in Prince William Sound since the earliest impact studies in the 70's and it was not until 1993 that a complete cycle of phytoplankton was measured (via the C-LAB buoy). Throughout the oil spill recovery period there has been no measurement of ambient nutrient conditions or phytoplankton biomass and production. Consequently, what is often considered a major deterministic variable of food webs in other marine systems has been ignored in these damage and restoration studies.

This project is one part of the multi-component SEA and Related Studies program in Prince William Sound, which has been designed to provide a comprehensive ecosystem-based understanding of restoration in upper trophic levels, specifically in pink salmon, herring, marine bird, and marine mammals. Within SEA, the Phytoplankton and Nutrient project will work most closely with the Physical Oceanography/Meteorology, Zooplankton, and Ecosystem Data Base

and Modeling projects. The phytoplankton and nutrient work proposed here will provide data for the examination of the temporal and spatial variability in the chemical and primary production fields, and for the testing of the hypothesis of "bottom-up" control of recovery in the Prince William Sound ecosystem. The analyses from this project also provide the patterns of response of phytoplankton and primary production to oceanographic and climate changes that can be used by all projects to test ideas about good vs. bad years in fluctuations of other target species.

A. Objectives

This study is designed to investigate the role of phytoplankton productivity and nutrient cycles in ecosystem restoration. This includes the pattern, amount, and type of phytoplankton growth and the major inorganic nutrient fields associated with the growth processes. Our hypothesis is that variations in the phytoplankton production and populations, as functions of ocean mixing, nutrients and light, are transferred to the zooplankton and these processes are crucial to ecosystem restoration.

The specific objectives are:

1. To measure the timing and biomass of phytoplankton cycles;
2. To measure the primary production of phytoplankton;
3. To determine the spatial and temporal patterns in phytoplankton distribution using satellite imagery;
4. To determine the species structure of phytoplankton communities;
5. To measure the distribution and quantity of major inorganic nutrients including nitrate + nitrite, ammonium, phosphate, silicate and iron;
6. To maintain the moored instrument array (C-LAB) to collect time series data on phytoplankton (fluorescence) and related oceanographic and climate data;
7. To evaluate the role of phytoplankton and nutrient cycles in restoration processes through the SEA ecosystem model.

B. Methods

Field work will be done in conjunction with other projects that require a vessel and from shore sites (hatcheries). We need two people on a cruise to accomplish the work program. When vessel time is not available, we will conduct work from a shore base at the PWSAC Esther Island or Sawmill Bay hatchery. Timing of the field work must be arranged to cover the spring phytoplankton increase (March-April). Based on the limited historical data and the excellent record obtained in 1993-94 by the C-LAB buoy, the sampling period should begin in mid-March

and extend to July. Discrete sample times can be integrated with the assistance of the continuous chlorophyll record obtained from the C-LAB buoy sensor array and satellite data.

Phytoplankton Biomass, Spatial and Temporal Patterns

Phytoplankton biomass will be determined using the standard chlorophyll technique using a Turner Designs Fluorometer. Data will be collected at locations that allow mapping the areal pattern and at selected depths that describe the water column profile. At each location (station) water samples are collected with a Niskin Sample Bottle and an aliquot (0.5 to 1 liter) filtered to collect the contained plankton. The chlorophyll in the sample is extracted with the appropriate solvent and the fluorescence of the solution measured quantitatively with the fluorometer. Chlorophyll units are converted to carbon biomass using carbon to chlorophyll ratios determined from the field samples.

Phytoplankton Primary Production

The biomass pattern provides a picture of what is present, but it does not provide information on phytoplankton dynamics. For example, a phytoplankton population with a relatively low chlorophyll value may be growing rapidly, but not exhibiting an increase in chlorophyll concentration due to strong grazing by the zooplankton community. To determine the actual primary production rate, we will use a labeled inorganic carbon tracer to measure direct uptake of carbon by phytoplankton photosynthesis. As with chlorophyll, the measurements will be on samples from discrete depths that represent the phytoplankton community distribution in the water column. We will use standard techniques for deck incubations with more recent modifications to avoid contamination.

Field sampling will be based at PWSAC hatcheries or, when available, conducted on board ship with experiment incubations performed using natural or artificial light, depending on the location and capabilities of the site. Since these are time-dependent measurements, they will be done once per day.

Phytoplankton Community Composition:

While biomass and rate measurements provide information on the availability of food, they do not give insight on the potential quality of phytoplankton as food. This requires a more detailed examination of the plant community composition. The composition of the phytoplankton community may be as important as the total primary production in determining zooplankton species and abundance. We use 25 ml aliquots and preserve them in Lugol's solution for later species identification using inverted microscopy. In 1995, we will monitor the distribution of phytoplankton and other particulates using a WET Labs Dual Path Absorption and Attenuation Meter (available from another project). This instrument can be configured to provide continuous attenuation and chlorophyll absorption measurements from an underway vessel. We will analyze the resulting distribution of phytoplankton and other particulates to monitor spatial and temporal changes in chlorophyll concentration and particle size distribution.

Satellite Image Analysis:

Satellite images are a powerful integrative tool. Once we obtain some field samples for ground truth data, images are valuable sampling mechanisms to examine the pelagic ecosystem on a broad geographic scale and over the entire year. We use NOAA Advanced Very High Resolution Radiometer (AVHRR) imagery from the University of Alaska Fairbanks High-Resolution Picture Transmission (HRPT) ground station. This station has been operational since 10 August, 1993. The AVHRR data is processed to produce sea-surface temperature images of the region. We use these images to monitor the inflow of water to Prince William Sound and to determine the spatial extent of water masses identified by the field program. This information will be available to all SEA investigators. We will acquire ocean color imagery of Prince William Sound from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) after the launch of the SeaStar satellite in September, 1994. Images of chlorophyll distribution are possible from the SeaWiFS data using both Terascan and Seapak image processing software. We will analyze the chlorophyll and sea-surface temperature images to determine the spatial and temporal variability in the surface water masses and phytoplankton in the sound throughout the year. The satellite data will allow us to put the field data into the correct spatial and temporal context. D. Eslinger will be responsible for providing the processed AVHRR (and SeaWiFS imagery to NASA approved SeaWiFS investigators) as part of the Ecosystem Data Base and Modeling project.

Nutrient Fields:

Phytoplankton require the major inorganic nutrients -- nitrogen, phosphorus and silica-- for growth. Nutrients are supplied by the general oceanographic circulation and run-off. Since phytoplankton also require light, the problem is understanding how the nutrients are supplied to the illuminated zone of the sea. Here we will gather quantitative data on the distribution of nutrients throughout the phytoplankton growth season. We expect that the depletion of nutrients will be the major factor that defines the period of high phytoplankton growth. In the field, water samples are collected with Niskin Bottles at standard depths over the upper 100 m (deeper if necessary). A small aliquot (250 ml) is filtered and frozen for later chemical analysis. Chemical determination of the quantity of dissolved nitrogen (as nitrate, nitrite and ammonium), phosphate and silicate will be measured using prescribed methods with an Alpkem Auto-Analyzer in our laboratory in Fairbanks.

Moored Instrument Array: The C-LAB Buoy

In 1995 this project will take over the C-LAB moored instrument program developed by Dr. Cooney with support from the Alaska Science and Technology Foundation (ASTF). The ASTF support ends in 1994. The moored instruments provided two years of continuous data from the sound that has seminal value to all SEA projects (e.g. Figure 1). Here we assume the responsibility for maintaining and upgrading the mooring to insure quality data are available to SEA. The buoy continuously acquires wind speed and direction, barometric pressure, air temperature, sea surface temperature, chlorophyll fluorescence, and ocean temperature at 10 depths. The moored instruments provide a mechanism to integrate other discrete observations collected from ships or shore stations. The winter data are especially valuable since no other sampling is done at this time. The data presented (Fig. 1) are but a small subsample of those available; they show the spring increase in phytoplankton (i.e. chlorophyll fluorescence) and

corresponding air temperature that has an obvious effect on the timing and pattern of the phytoplankton bloom. The budget reflects the costs for assuming the C-LAB mooring. Actual replacement cost would be more than five times the amount included here.

Data Sharing:

All data from this project will be available electronically to the modeling project. We also expect to interact extensively with the modeling effort and the development of a coupled physical and primary production sub-model.

C. Schedule

This project will be conducted in 1994 and 1995. The field season will concentrate on the period March--July. All laboratory analysis of samples will occur following the field season. Satellite observations will begin in 1994 and continue throughout the duration of the project.

D. Technical Support

Nutrient analysis and phytoplankton species identification will be performed at the Institute of Marine Science Marine Ecosystem Laboratory at UAF using existing facilities. Field observations of chlorophyll will initially be performed using a Turner Designs flow-through fluorometer. Satellite image analysis will be performed at the IMS Remote Sensing Laboratory at UAF utilizing both Terascan and Seapak analysis packages.

E. Location

Prince William Sound

COORDINATION OF INTEGRATED RESEARCH EFFORT

The SEA phytoplankton and nutrient project will interact with other SEA projects by contributing information on the role in restoration processes of the timing and intensity of the spring phytoplankton bloom, the character and composition of the bloom, and the spatial extent and variability of the bloom and nutrient concentrations. We will interact with the physical and meteorological components to determine the effects of advective and mixing processes on nutrient and phytoplankton distributions. We will collaborate with the zooplankton project to determine the importance of in situ Prince William Sound primary production in determining the zooplankton dynamics and how this interacts with the river/lake hypothesis. We will work closely with the data and modeling project to provide appropriate parameter measurements and field "truth" data with which to check the model, and will help in the development of a nutrient, phytoplankton, zooplankton component for the model.

FY 95 BUDGET (\$K)

Personnel	3.0
Travel	0.0
Contractual	230.2
Commodities	0.0
Equipment	0.0
Subtotal	233.2
Gen. Admin.	6.1
Total	239.3

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Role of Zooplankton in the Prince William Sound Ecosystem

Project Number:	95320H
Restoration Category:	Research (continuation of 94320H)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cost FY 95:	\$247,400 (includes \$51,900 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$307,200
Total Cost:	Unknown
Duration:	3-5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

This proposal requests funding in FY95 to continue studies of the role of large zooplankton in the trophic ecology of Prince William Sound as part of the EVOS-sponsored Prince William Sound System Investigation (95320). The premise behind this research is that appropriate restoration activities can only be conducted within the framework of understanding how the marine ecosystem constrains the production of pink salmon and herring. The work described here is prefaced by a reviewed literature that documents that most of the mortality to a year class occurs in the early life stages.

A central hypothesis for the overall integrated ecosystem approach is that levels of predation on 0-class pink salmon and herring (and other fishes) are modulated each year by the amount of macrozooplankton present during the critical months of April and May. During years of high macrozooplankton abundance, all consumers (including 0-class fishes) derive substantial nutrition from plankton. Under these conditions, juvenile salmon and larval/post-larval herring are "sheltered" from predation, and losses to larger fishes are minimized. In contrast, during years (and seasons) when macrozooplankton populations are weak, consumers shift to piscivory, and losses of 0-class fishes (including salmon and herring) to predation are substantially elevated.

Data from other studies of the region indicate that flushing rates of the Sound's upper layers in April apparently modify amounts of large zooplankton (*Calanus/Neocalanus*) comprising a predictable early-season bloom. When the flushing rate is high, forage for juvenile pink salmon and herring is depleted by washout from the region. In contrast, when wind-forced flushing rates are low, the Sound retains these forage populations in higher densities. Seeding the Sound with overwintering forms in the summer from the adjacent deep ocean is also implicated in determining the amounts of subsequent springtime macrozooplankton in the surface layers.

Understanding how prey-switching is influenced by wind and buoyancy-forced transport (Physical Oceanography component), and relating levels of zooplankton-modulated predation during the early life stages of pink salmon and herring to subsequent adult production, provides a crucial benchmark for judging these and other factors (including oil related) that may be limiting the recovery of these injured species. The application of this information is fundamental to the larger question of restoration - activities and interventions - that can be evoked to return pink salmon and herring populations to healthy pre-spill levels.

NEED FOR THE PROJECT

Pink salmon and herring populations in Prince William Sound are listed by the EVOS Trustee Council as injured resources that are not recovering. Together, these two species have historically contributed about \$40-50 million dollars to commercial fisheries, are harvested for subsistence use, provide substantial recreation and tourism opportunities, and play keystone roles in the overall ecology of the region. Unexplained failures in production following the EVOS have had tragic economic consequences for all the communities of Prince William Sound and surrounding areas. Understanding why these production trends have occurred is central to implementing appropriate restorative measures.

This proposal, in collaboration with the other components of the Sound Ecosystem Assessment (SEA) program for FY95, will provide the Trustees and their agents with information on ecosystem dynamics that can be used to more accurately evaluate damage to injured species and to eventually design appropriate restorative measures. Unless the dynamics of the PWS ecosystem are well understood, actions taken to restore pink salmon, herring and other non-recovering species may be inappropriate, ineffectual, or even damaging to the system. As discussed above, macrozooplankton populations are hypothesized as playing a pivotal role in regulating levels of planktivory and piscivory in the region's consumer populations.

PROJECT DESIGN

The ecosystem approach adopted by SEA in FY94 utilizes a multi-component, integrated project format to quantitatively address hypotheses linking pink salmon and herring production to biological interactions (like growth and predation) that are also strongly modified by environmental factors (temperature, rates of flushing, fronts and eddies, water column stratification). The zooplankton component will be responsible for describing the role that

large and small calanoids, amphipods, euphausiids, pteropods and other dominant pelagic forms play in supporting pink salmon and herring production each year.

A. Objectives

1. Use continuing PWSAC hatchery zooplankton watch collections to describe the timing, duration, magnitude and species composition of springtime upper-layer (20 m) zooplankton stocks in northern, western and southern Prince William Sound.
2. Use shipboard collections of zooplankton to describe how ontogenetic and diel shifts in vertical distribution influence trophic coupling between juvenile fishes and higher-level consumers (in collaboration with Prey/Predator and Juvenile Salmon and Herring Growth studies).
3. Provide direct measures of the species composition and indices of abundance for macrozooplankton swarms and layers detected simultaneously with high-frequency acoustics and optical plankton counting techniques (in collaboration with Nearshore Fish component).
4. Describe how the timing, magnitude and duration of the phytoplankton bloom influences the timing, duration, magnitude and developmental rates of upper-layer macrozooplankton populations (in collaboration with Phytoplankton and Nutrients).
5. Work cooperatively with all other components of SEA to affect formal tests of Lake/River and Prey/Switching hypotheses (in collaboration with Information Services and Modelling).
6. Provide taxonomic assistance (when requested) to ADFG personnel at the Soldotna Limnological Laboratory, and establish a voucher collection of major zooplankters and life stages.

B. Methods

Zooplankton populations will be sampled with nets, including 60-cm bongo nets, 1-m opening-closing NIO nets, 1/2-m closing ring nets, and 1/2-m open ring nets. Most nets will fish 0.333-mm Nitex mesh to assure that the early stages of target populations will be collected. For larger macrozooplankton and micronekton (euphausiids, shrimps, amphipods), a larger mesh - 0.505 or 1.000-mm may occasionally be used.

When appropriate, these nets will be equipped with calibrated flow meters to measure the volumes filtered for each collection. Depth of sampling will be determined using a acoustically-linked net sounder (real time) or time-depth recorder and meter wheel (scope). Discrete depth samples will also be obtained by closing vertical and horizontal tows activated by messenger from the surface. All nets will be carefully rinsed and collections preserved in approximately 10 percent seawater formalin for later laboratory analyses.

In the laboratory, collections will be screened for large or otherwise obvious zooplankters (direct counts) and then subsampled (Folsom splitter and/or Stempel pipet) for the more numerous organisms. To ensure representative sampling, between 100 and 150 animals will be counted. In the case of the larger calanoids, copepodite stages will be enumerated separately. Samples will be analyzed at the ADFG Limnology Laboratory in Soldotna, Alaska, and at the University of Alaska Fairbanks campus.

Sufficient replication will be undertaken to measure field sampling error, and levels of variability associated with day:night, location and cruise (date). Differences will be examined using ANOVA and other parametric and nonparametric statistical techniques.

Important data on continuous seasonal changes in upper-layer plankton stocks (species composition and abundance) will be obtained from the PWSAC hatchery plankton watch program. Samples are collected twice-weekly at locations adjacent to each facility (Evans Island, Esther Island, Cannery Creek and Main Bay) in open 20-m vertical tows. After the hatcheries have measured the settled volumes of these collections, the samples are preserved in 10 percent formalin and stored for analysis at UAF. The hatchery watch program monitors upper-level plankton fields from 1 March through 30 June of each year.

Net samples will be taken aboard ship to identify zooplankton fields associated with layers or swarms of acoustically-censused and optically counted plankton (see Information Services and Modelling component). Sufficient direct sampling will be undertaken to assure the identity of the major species and to provide indices of their abundance and biomass.

A twice-monthly series of closing vertical tows in the deep region near Lone Island will provide profiles of upper-layer and deeper populations to track ontogenetic migrations. Sufficient sampling will be conducted at night from the ship to describe diel behavior and the extent to which day/night vertical movement influences the hypothesized prey-switching mechanism.

Sampling at least twice weekly at designated hydrographic stations along acoustic transects will provide a comparison with hatchery measured zooplankton in all regions. Particular attention will be paid to documenting the period when late-stage oceanic copepods (*Neocalanus* spp.) leave the surface waters (late May, early June). This abrupt decrease in upper-layer macrozooplankton provides a "river-like" experiment each year against which the degree of planktivory or piscivory can be judged. Knowing when the *Neocalanus* spp. descend from the surface is crucial to testing shifts in consumer prey fields.

C. Schedule

October-January	Complete FY94 data analysis.	Begin staging for FY95.
January-February	Complete staging for FY95.	Initiate FY96 planning.
March-July	Conduct FY95 field work.	Continue FY96 planning.
August-September	Analyze field data and prepare preliminary reports for workshop.	

D. Technical Support

Laboratory taxonomic services will be supplied by the project leader's laboratory in Fairbanks. Samples will be delivered to Fairbanks during the season using monthly aircraft charters from Anchorage linked with a van from Fairbanks. Computer services will be available at the University of Alaska Fairbanks and through SEA facilities at the Prince William Sound Science Center. Data archiving will be undertaken cooperatively with the SEA Information and Modelling component.

E. Location

Zooplankton sampling will be conducted in Prince William Sound, with emphasis being given to the central and western areas serving as the rearing and migratory pathways for juvenile pink salmon and herring.

PROJECT IMPLEMENTATION

This project represents a continuation of research begun in FY94 as part of the coordinated Prince William Sound System Investigation, Sound Ecosystem Assessment program under a reimbursable services agreement (RSA) with Alaska Department of Fish and Game. Programmatic structure is in place to continue a second year of study with ADFG sponsorship.

COORDINATION OF INTEGRATED RESEARCH EFFORT

SEA-ZOO is one of 13 projects being coordinated as the FY95 SEA investigation of Prince William Sound Zooplankton information contributes to tests of the Lake/River hypothesis, the Prey/Predator hypothesis, the Herring Overwintering Hypothesis, and to the SEA data base and modelling activity.

FY 95 BUDGET (\$K)

Personnel	3.0
Travel	0.0
Contractual	238.1
Commodities	0.0
Equipment	0.0
Subtotal	241.1
Gen. Admin.	6.3
Total	247.4

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SEA: Confirming Food Web Dependencies in the Prince William Sound Ecosystem Using Stable Isotope Tracers - Food Webs of Marine Mammals and Birds

Project Number:	95320I(1)
Restoration Category:	Research (continuation of 94320)
Proposed By:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cost FY 95:	\$115,400
Cost FY 96:	\$115,400
Total Cost:	\$230,800
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harbor seal

INTRODUCTION

This project contributes to an ongoing effort by Alaska Department of Fish and Game personnel to determine the reasons for the decline of harbor seal and steller sea lion populations in Prince William Sound. In addition, the project seeks to better describe the trophic interactions and trophic status of marine mammals, birds and their prey species in the Prince William Sound ecosystem. The integrating methodology for the range of tasks is the use of stable isotope ratios as natural tracers of carbon and nitrogen transfers through the food webs. Carbon isotope ratios serve as conservative tracers of energy supply between trophic levels (phytoplankton to zooplankton to fishes to top consumers). Seals, cetaceans, birds etc., acquire the isotope ratios in proportion to the amount of food derived from each differing source. This, in turn, is reflected in the composition of body tissues and in keratinous tissues (claws, feathers, baleen, whiskers) as a temporal record when multiple sources of food are consumed over time and space. This allows the discerning of important habitats and food resources in animals that seasonally migrate or undergo periods of hyper- and hypotrophy.

Nitrogen isotope ratios reflect both the food sources and the trophic status of the animal. As nitrogen in food is consumed and assimilated by a consumer, the heavy isotope is enriched by approximately 3‰. This enrichment occurs with each trophic step and thus allows the

construction of conceptual models and food webs within the ecosystem and the assignment of trophic status to species for which field data on diet are sparse.

In cooperation with Dr. T. Kline, who is focusing on the fishery resources of the PWS pelagic food webs, we are collecting a suite of samples aimed at allowing us to model the trophic structure of the PWS and the habitat dependencies. Over the past year we have collected offshore forage fishes and tissues from marine mammals. This collection program is now again under way and a large collection of samples for isotope ratio analysis has been obtained. After reviewing the results of this effort, we will focus on areas of data gaps and on refining our understanding of ecosystem processes controlling distributions of isotope ratios.

NEED FOR THE PROJECT

This study focuses on harbor seals, sea birds and the cetaceans of Prince William Sound. Although the major effort is concerned with harbor seals, other marine mammal tissues will be collected opportunistically in cooperation with those agencies handling or collecting those species. Our principal cooperating agency is the Alaska Department of Fish and Game.

This study is closely coordinated with the modeling efforts and the pelagic food web studies being undertaken by the Prince William Sound Science Center personnel. Dr. Kline is responsible for most pelagic collections of food base organisms and is sharing these data to help construct the food web models. Stable isotope data provide an excellent means for validating models and testing food web linkages. This aspect of the work will be cooperative with many components of the SEA project.

PROJECT DESIGN

A. Objectives

1. Collect samples of harbor seal vibrissae through cooperative work with the Alaska Department of Fish and Game in Prince William Sound;
2. Collect samples of harbor seal prey species including forage fishes, salmon and herring in the vicinity of major haul-outs and high population densities. Samples of seal tissues will be collected from native hunters. These samples will be obtained through assistance by ADFG personnel monitoring harvests.
3. Perform stable isotope ratio analyses on tissues and organisms collected during the sampling program. Through the use of carbon isotope data on taxa collected over geographical regions, the presence/absence of isotopic gradients useful in sorting out habitat dependencies will be determined.

4. Through the use of nitrogen isotope ratios in collected taxa, assign trophic status to species in each region. Compare trophic status with predictive models based on conceptual food webs.
5. Determine temporal changes in harbor seal trophic status and food dependencies by comparing isotope ratios along the lengths of vibrissae with prey availability and their isotope ratios.
6. Compare the isotope-ratio derived food web models to predictions by the "lake- river" hypothesis of the SEA project as an independent means of validation.

B. Methods

The primary work will be divided into the sampling program and the subsequent analytical and synthesis tasks. Sampling of tissues for stable isotope analysis has been described for both bulk tissues (muscle, blubber) and temporally variable tissues (whiskers, claws etc.).

Analytical: The samples obtained are dried and powdered for homogeneity and the isotope ratios of carbon and nitrogen determined with a Europa 20/20 mass spectrometer system. The sample is combusted at high temperature and the nitrogen and carbon dioxide gases separated and purified by gas chromatography. These are subsequently led into the mass spectrometer by capillary and the isotope ratios determined.

Synthesis of data: The plots of isotope ratios of carbon and nitrogen along the lengths of vibrissae from sea lions are known to show oscillations in isotope ratios in response to dietary changes over the seasons. As new data with supporting natural history information are acquired, the values at specific intervals will be compared with potential prey for likely matches. These will be compared with observational data and known feeding habits. From this information, sampling can be constrained to the most probable food sources and further directed analyses performed to confirm or deny conceptual food web structure.

C. Schedules

1 Nov 94 - 15 Feb 95	Prepare and analyze isotope ratio samples
15 Feb - 31 March 95	Synthesis and coordination for sampling
Apr - August 95	Field work and sampling
Aug - Sept 95	Post field analysis and planning for 1996

D. Location

The research effort will be conducted in Prince William Sound with contrasting data obtained from samples from the Kodiak Island area and in the coastal Gulf of Alaska near Cordova.

E. Technical Support

This project is integrated closely with the ADFG program on marine mammals in the Prince William Sound and adjacent areas. Other collaborators in NMFS and the University of Alaska will contribute samples from their programs to this project.

FY 95 BUDGET (\$K)

Personnel	7.2
Travel	0.0
Contractual	100.1
Commodities	0.0
Equipment	0.0
Subtotal	107.3
Gen. Admin.	8.1
Total	115.4

SEA: Confirming Food Web Dependencies in the Prince William Sound Ecosystem Using Stable Isotope Tracers - Food Webs of Fishes

Project Number:	95320I(2)
Restoration Category:	Research (continuation of 94320I)
Proposed By:	Prince William Sound Science Center
Lead Trustee Agency:	ADFG
Cost FY 95:	\$79,400 (includes \$30,000 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$176,000
Total Cost:	Unknown
Duration:	2-5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Multiple resources

INTRODUCTION

Stable isotope ratios of carbon can serve as effective tracers of energy supply in Prince William Sound (PWS) due to conservative transfer of carbon isotope ratios between the lower trophic levels (phytoplankton to zooplankton to forage fishes, etc.) up to the top consumers. Isotope ratio analysis of fishes, their prey and their predators can provide insight into habitat usage and assist in quantifying diet derived from various areas. Nitrogen isotope ratios, in turn, provide excellent definition of relative trophic level. The heavy isotope of nitrogen is enriched by about 0.34‰ with each trophic level and thus can accurately indicate the relative trophic status of species within an ecosystem. The data obtained from these measurements are unique in that they trace material actually assimilated and thus can be used for more accurate ecosystem modeling.

The availability of macrozooplankton forage for salmon, herring, and their predators varies in space and time because of changes in physical processes in Prince William Sound. In the SEA context, the latter is known as the Lake/River processes (SEA hypothesis number 2). When macrozooplankton are not available, macrozooplankton consumers are forced to switch prey, thus predator-prey relationships (SEA hypothesis number 3) shift in space and time. These shifts may represent fundamental changes in the way the PWS ecosystem produces commercial species (i.e. herring and salmon). A better understanding, particularly a quantitative

understanding, is a prerequisite to determining protocols for restoration and recovery of these fishes.

It can be postulated that natural stable isotope abundance of PWS biota will reflect changes in trophic level, food web structure, and primary production, thus providing an independent tool to verify, quantify and model ecosystem processes. The tracer nature of the approach will enable the integration of ecosystem components. It will enable us to monitor both "top down" (predatory) and "bottom up" shifts (food supply) in herring and salmon production.

NEED FOR THE PROJECT

This project is an interdisciplinary effort focused on the food web dynamics supporting top trophic levels in Prince William Sound. The study provides an integrating function to projects focusing on several levels in the food chains and will employ the stable isotope ratios of carbon and nitrogen to trace trophic transfers of these elements between levels. One focus is to build the data base regarding harbor seals whereas the remaining work will seek to build a comprehensive base of isotopic data for the Prince William Sound region. In cases where regional gradients in isotope ratios exist, it may also be possible to identify critical habitats used by marine biota.

Observations made during Leg 1 of SEA cruise 1 of 1994 confirms the concept that Prince William Sound is a pelagic system. The principal midwater predator was pollack utilizing macrozooplankton (euphausiids, copepods, squid, and isopods) as prey with occasional use of fishes. Shortly after commencement of pink salmon release at Lake Bay, approximately one in 15 pollack sampled in Wells Passage preyed upon salmon fry, and this predation was exclusive. At this time pollack were widely dispersed in the area suggesting opportunistic feeding depending on encountering salmon.

PROJECT DESIGN

The Stable Isotope study is part of the integrated Prince William Sound System Investigation initiated in FY94. The Stable Isotope study will integrate with virtually all other aspects of SEA and the Prince William Sound System Investigation.

With SEA (other 320 projects):

Salmon Growth and Mortality: Stable isotope data of growing salmon will be compared to available forage fields to ascertain flow of nutrients to salmon. Stable isotope data will be used to assess significance of salmon prey to salmon predators.

Salmon Predation: Stable isotope data of predators will be used to assess their role in affecting salmon and herring recruitment.

Phytoplankton and Nutrients: Stable isotope data of zooplankton will be used to infer changes in the availability and flow of nutrients at the bottom of the food chain.

Zooplankton in Ecosystem: Stable isotope data of zooplankton will be used to assess their

trophic levels and infer the dynamics within the zooplankton-pelagic community.

Information Systems-Modeling: Stable isotope data will be used to determine canonical trophic levels and to reconstruct food webs. This information will be incorporated into models. Isotopes shifts will be used as empirical spatial and temporal inputs.

Physical Oceanography: Stable isotope data of pelagic food webs recorded in temporal and spatial context will be compared with physical oceanographic data to ascertain the relationship of circulation patterns with changes in food web dynamics.

Nearshore Fish: Stable isotope reconstruction of pelagic food chains will be related to predator and prey fields as ascertained by hydroacoustic measurement and netting.

Avian Predation on Herring Spawn: Stable isotope analysis of herring predators will be used to assess role of herring spawn to avian diets in Dr. D. Schell's related studies. The isotopic signature of herring and alternative avian marine prey will be derived in the fish food web component.

Herring natal habitats: Stable isotopic chemistry of natal habitat predators will be used to assess their herring roe predation role.

Juvenile herring growth and habitats: Stable isotopic chemistry of juvenile herring will be used to assess their trophic status in relation to growth rate in different habitats.

Herring predation by humpbacks: The established isotopic database of herring and other potential humpback prey will be used to assess the isotopic chemistry of any humpback samples that become opportunistically available (e.g. from sloughed skin or carcasses).

With related studies:

CWT Recovery: Stable isotope data of salmon with CWT can be used to assess ecosystem utilization by this subpopulation with respect to other species and pink salmon in general.

Pink Salmon Genetics: Stable isotope data can be correlated with genetic data to expose ecological and genetic relationships, e.g. the question of whether carrying capacity effects are the cause of dwarfing in pinks.

Harbor Seals (Trophic Interactions): Stable isotope data from the fish food web component will provide the spatial and temporal background data needed to interpret isotope data of seals.

Trophic-Stable Isotopes: Stable isotope data from this component will support Dr. D. Schell's investigation on seal and avian predation.

Bald eagle diet: Analysis of eagle feathers and samples of eagle prey will rely this isotopic database for interpretation.

Larval and juvenile herring in PWS: Interpretation of isotopic analysis of juvenile herring will augment the larval and juvenile herring study.

A. Objectives

This project has two hypotheses: (1) Carbon and nitrogen stable isotope ratios of biota from Prince William Sound can be used to identify major food sources to top trophic levels and to assign trophic positions to specific consumers of given age classes and habitat; (2) Isotope ratios in consumers provide a means to validate conceptual food web structures, identify trophic variability by individuals within species, and to validate quantified energy flows in ecosystem models.

Specific objectives of this project are:

1. To determine the $^{15}\text{N}/^{14}\text{N}$ and $^{13}\text{C}/^{12}\text{C}$ of species collected from the Prince William Sound ecosystem with a focus on those components important to man or important in the food webs supporting these species. Herring and salmon collected from PWS will be matched with regional isotope abundances in prey species (zooplankton, forage fishes) to allocate food sources and to assess trophic transfer efficiencies in specific areas of the Sound.
2. Determine isotope ratios of prey species that are favored by marine mammals in different regions of Prince William Sound. These data will allow estimation of seasonal importance of various prey species and the trophic levels of various seal species in the ecosystem. Past data has shown that there are considerable differences between individual animals of a given age and also changes in trophic level over the life span. Drs. Schell and Kline expect to consult with each other frequently to exchange data to develop this and other parts of the stable isotope program.
3. Synthesize the data obtained in context with conceptual food webs to validate feeding models and expand the natural history information.
4. Contribute stable isotope results to formal tests of the Lake/River-driven prey switching hypothesis developed by SEA to explain pink salmon and herring production trends.

B. Methods

Strategy

1. Collect synoptic samples from the greater PWS using the available fleet (ADFG et al.) sampling effort. Under other SEA projects, these same individual samples will receive additional analyses (e.g. stomach content analysis) in addition to the stable isotope analysis described.
2. Post-season analysis will reveal where macrozooplankton were and were not available to consumers (this will be discussed among collaborators at the fall workshop)
3. Conduct a posteriori tests of trophic level and food web shifts on samples from appropriate sites using the natural stable isotope methodology

Analytical methods

The methodology involved in the isotopic analyses and the interpretation of the data are well established and documented in several publications resulting from prior work of the Principal Investigator. The UAF Stable Isotope Facility has three isotope ratio mass spectrometers including a new automated system which facilitates faster sample processing and allows more replication in small samples.

Sampling protocols in the field for zooplankton and fishes are well established and will be used in any future sampling. Predator isotopic data will be compared with values obtained from prey species in the same habitats. Where samples of prey species are missing or few, we will try to select proxy samples from the same area (zooplankton, benthos) which will enable a similar comparison. After the isotopic values are in hand, we will synthesize the data with existing data on isotope ratio values (published and unpublished) to establish a trophic model.

C. Schedules

Fall 1994	Conduct fall field sampling cruise on Alpha Helix. Subsampling and preparation for isotopic analysis will be continued as time permits.
Fall/Winter 1994-95	The collected samples will be analyzed for $^{15}\text{N}/^{14}\text{N}$ and $^{13}\text{C}/^{12}\text{C}$ and a conceptual trophic and food web model assembled for the Prince William Sound ecosystem with the focus on commercially important species.
Spring/Summer 1995	The data obtained will be used in the preliminary models to identify data gaps and to direct summer 1995 sampling operations. Summer sampling will be undertaken in close cooperation with other projects to optimize sampling and to help validate/test other models of ecosystem interactions by species of interest. Manuscripts describing the results will be prepared for the open scientific literature. Planning for FY96 will take place.

D. Location

The sampling will be carried out throughout PWS as part of the cruise plan. Analytical work will be carried out using the stable isotope facility at UAF. Sample preparation for stable isotope analysis and data interpretation will take place at the Prince William Sound Science Center.

E. Technical Support

Alaska Department of Fish and Game - Vessels and sampling
University of Alaska Stable Isotope facility - Dr. D. Schell will receive prepared samples from Dr. Kline. Dr. Schell will supervise the isotopic analysis and reporting of data to Dr. Kline.

FY 95 BUDGET (\$K)

Personnel	3.0
Travel	0.0
Contractual	74.4
Commodities	0.0
Equipment	0.0
Subtotal	77.4
Gen. Admin.	2.0
Total	79.4

Sound Ecosystem Assessment (SEA) - An Ecosystem Study for Prince William Sound: Information Systems and Model Development (SEADATA)

Project Number:	95320J
Restoration Category:	Research (continuation of 94320J)
Proposed By:	Prince William Sound Science Center
Lead Trustee Agency:	ADFG
Cooperating Agencies:	DOI, NOAA
Cost FY 95:	\$836,200 (includes \$265,700 for data analysis and report writing on FY 94 work)
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	2-5 years
Geographic Area:	Prince William Sound and North Gulf of Alaska
Injured Resource/Service:	Multiple resources

INTRODUCTION

The Information Systems and Model Development Project (SEADATA) for FY95 is one of thirteen projects within the Sound Ecosystem Assessment (SEA) program. It will be a continuation of the FY94 project 94320J, begun in April 1994.

The Sound Ecosystem Assessment (SEA) Initial Science Plan and Monitoring Program describes the manner in which pink salmon and Pacific herring, among all marine species exhibiting injury following *EVOS*, are economically and ecologically unique. The SEA Plan presents a set of hypotheses regarding the key ecosystem components and processes that may regulate the recovery of these species. The resultant SEA Program is a coordinated collection of projects, most of which address one or two key ecosystem components encompassing the ocean environment, phytoplankton, zooplankton, nearshore and pelagic fish populations, and shore birds. These projects have been designed to maximize the simultaneous measurement of different system components and then to combine all the resultant information into a common data system. The ultimate objective is to achieve an integrated ecosystem representation of processes affecting recovery of the injured species. It is this objective that defines the purpose of the SEADATA project.

SEADATA will develop two ecosystem representations for SEA:

Descriptive model representation: A spatially and temporally sparse, observationally determined representation of the state of the system.

Numerical model representation: A more complete system representation by means of data along with quantitative descriptions of relations among system components.

In addition, the SEADATA project will undertake two subprojects to reduce the impact of sparse sampling on the quality of the representation and to utilize optimally the monitoring effort: near realtime field communications and enhancement of monitoring scope per unit of monitoring cost.

Descriptive Model Representation

The descriptive model representation is conceptually the collection of all observations from SEA and from other data sources. The FY94 SEA projects are now acquiring the following information about the state of the system (items marked with * will be operational later in FY94 or in FY95):

From the SEA field survey (buoys, surface vessels, aircraft*):

- ocean current vectors, temperature, salinity, sea state, fronts
- plankton densities, distribution, species and cohort composition
- fish densities, distribution, size and species composition, diet
- bird and mammal counts, distribution, diet

From the satellite downlink site:

- sea surface temperature (Advanced Very High Resolution Radiometer - AVHRR)
- ocean color and derived values (Sea viewing Wide Field of view Sensor -SeaWiFS*)
- meteorological data*

The descriptive model will be realized as an online digital data system with a well integrated library of query and analysis software tools specifically selected and adapted for multivariate, three-dimensional, time varying marine system data. This product can be thought of as a three-dimensional GIS (geographical information system) for the SEA program. The resultant comprehensive ecosystem database for Prince William Sound will have near realtime, online availability for all SEA investigators. In addition, SEA database products will be accessible electronically to the local community, including fishermen and citizens concerned about the current status of the Sound and the progress of restoration efforts, as well as to members of the Trustee Council and scientists worldwide via the Internet.

Numerical Model Representation

A numerical model representation refers to a set of quantitative relations between system components. Whereas the foregoing descriptive model presents the state of the observed system, a numerical model describes the functioning of the system. This information is fundamental to understanding and managing the recovery of injured species.

A first step toward such a model is the identification of the essential components of the system (the subsystem) and the relations between these essential components. For example, the river-lake hypothesis proposes specific components (macrozooplankton density, fry density, predator densities, ocean currents) and relations (foraging behavior, advective dispersion, annual vertical migration) as the essential subsystem regulating pink salmon fry predation over a specific time interval. In this case a numerical model would relate ocean currents to macrozooplankton distribution and relate macrozooplankton density and fry density to predator foraging behavior. Once such relations are validated they provide the means for quantitatively assessing how this subsystem affects recovery through changes in ocean current patterns or changes in predator populations. Such an assessment can address changes occurring naturally and, in the case of predators, changes in fisheries policies.

In addition, the accounting for fry survival through changes in ocean currents transfers the variability of a biological component to that of a physical system that is essentially deterministic. The use of only observational ocean current information is limiting in that the observations are sparse and the determinism of ocean circulation and maturity of circulation models are not exploited. Consequently, the SEADATA project first addresses the implementation of an ocean model as a fundamental component of the numerical models, whether statistical or deterministic, of the processes regulating recovery.

Numerical models are conveniently classified as ocean models, physical-biological models and nekton models. The first is deterministic and forcing on the second and third. Physical-biological models apply to those marine species whose transport is advective. Nekton models apply to fish. Physical-biological models and nekton models are fundamentally dependent on an ocean circulation model. The longterm strategy for numerical model implementation is the following. During FY95 and 96, the primary effort will be directed toward the ocean circulation model with only essential and collaborative activities in the other two modelling areas. Once an ocean model is online, efforts in the other two modelling areas will begin in parallel, with approximately equal effort allocated.

Near Realtime Field Communications

The sparseness of the sampling can in part be offset by adaptive field sampling strategies. Because of temporal variability, adaptive strategies require that new information be added in near realtime. Consequently, a companion objective of the SEADATA project for FY94 and beyond is a near realtime data communication system linking all sources of data, all data analysis sites, and all adaptive survey systems.

Monitoring Technologies

The sparseness as well as the cost of sampling can be reduced through the use of indirect measurement methods. Hydroacoustics for fish and satellite remote sensing for sea surface temperature have been used in SEA from the outset. During FY94 a towed platform (Chelsea, Ltd., Aquashuttle) that automatically follows a periodic depth varying path was added. All sensors, such as a CTD, carried on this platform periodically traverse a depth interval of the water column. A new indirect system, the optical plankton counter from FOCAL, Ltd., was also added in FY94. An ongoing objective of the project is to adapt such methods for use in

SEA when their use is cost effective. Autonomous systems are also an objective. During FY94 one or two buoys will be configured with basic monitoring sensors and with transmitters. These will be part of the near realtime data system. For FY95 the goal is to develop implementation plans for the addition of high frequency acoustics to the Aquashuttle and for the use of acoustic tomographic methods to utilize buoy stations more efficiently.

NEED FOR THE PROJECT

SEADATA functions as both a collaborator and a facilitator for all other SEA projects. It must collaborate with each project with respect to survey design, methods, data formats, reduction procedures, and data analysis; and it must facilitate communications, data transmission, data ingestion, data qualification and security, and the inclusion of project data into the broader framework of all SEA results. These functions are a principal mechanism in the SEA program for ensuring the development and execution of well coordinated surveys and the coordinated interpretation and dissemination of results.

Beyond this support role there is another central function: SEADATA provides the mechanism by which data from the separate SEA projects becomes an ecosystem assessment. Whereas the other individual SEA projects address issues associated with specific system *components* or processes coupling specific system components, SEADATA implements the SEA Plan *at the system level*. The project is responsible for integrative efforts including spatial and temporal coordination, summarization and visualization of data for multiple trophic levels and computation of trophic level interaction rates. In addition, a serious approach to model formulation is required to obtain quantitative information about recovering species, rates of recovery, and potential effects of restoration approaches upon recovery. Part of the mission of the SEADATA project is to select and apply appropriate models, using data derived from the SEA investigations and other sources, in order to obtain quantitative representation of subsystem function in Prince William Sound. Such representation is a prerequisite to the ability to understand and predict the impact of significant perturbations to the system, whether natural or man-made.

PROJECT DESCRIPTION

The FY94 project description for project SEADATA (94320J) outlines five major subprojects:

1. Field data communications;
2. Data management;
3. Descriptive model;
4. Numerical models;
5. Sampling technologies.

This FY94 subproject structure will be followed in FY95 and the task enumeration below is identical to that of the FY94 Detailed Project Description. The FY95 project plan, however, reflects changes in emphasis resulting from the completion of FY94 infrastructure and resource milestones (hardware, software, local and wide area network communications, personnel, and

collaborative agreements). The FY95 plan also reduces operating capabilities relative to those of FY94. By this means the same range and types of services are sustained over twelve months at a constant project cost.

1. Field data communications

During FY94 the core components and licenses for a UHF packet-radio realtime data communication system and repeater network will have been completed. Baseline functionality will have been established in three application areas: a single survey vessel, a single buoy, and an autonomous system. Given this status, it is appropriate technically to consider expanding this capability to additional survey vessels and to begin planning for a network of realtime *in situ* stations. However, to contain costs for FY95 this subproject will continue at a much lower level. No further in situ realtime stations will be added. No major effort for an expanded ship of opportunity program will be undertaken. The FY95 effort will focus on survey vessels. To the maximum extent possible, survey vessels will be fitted with realtime send and receive data communications, using the UHF repeater approach developed in FY94, to support data and model-based adaptive sampling schemes.

There will, in addition, be an effort to track and to utilize new developments in the Prince William Sound region as they appear. During FY95 cellular phone service will become available, but for a limited region. Also, a privately funded communications satellite has been announced. The costs and benefits of such new technologies will be evaluated.

2. Data management

All data-related tasks are collected into the data management project which, in turn, has seven subprojects.

2.1. Coordination: This subproject will continue to provide coordination of the data management project with the needs and interests of the SEA participants and the Trustee Council.

2.2. SEA data services: In FY95, data services will have achieved basic functionality objectives for mass storage, CD-ROM mastering, data ingestion, basic security, data quality control, and data access procedures. For most areas the effort will continue at a maintenance level. Implementation of a redundant array mass storage system will be postponed until FY96. For FY95 the focus will be on development of a scientific database system. During FY94 the Prince William Sound Science Center and the Advanced Visualization Laboratory, University of Maryland, were awarded dual grants by Xidak, Inc., of Palo Alto, California, of their scientific database and data server software (list value \$50,000 per site). Under this grant, the parties will undertake a cooperative development effort to address database and data server issues specific to the SEA Program. Xidak in addition is supporting a graduate student engaged in the project. This grant and the codevelopment effort is significantly accelerating the implementation of a scientific data system for SEA.

2.3. Site access: The subproject will continue to maintain both wide area and the local area connectivity. Wide area communications, including access to the Internet, are essential not only to the SEA investigators but also to the larger community served by and interested in the restoration effort, by providing for electronic communications, online data access, distributed databases, and network conferencing. In addition, this communication is necessary for activities such as the codevelopment with Xidak and the University of Maryland. Wide area and local area communications are also closely coupled with the realtime data communications project and both systems are required to realize realtime data dissemination and adaptive field sampling strategies. However, for FY95 the speed of the wide area network will be reduced from 256 Kbps to 56 Kbps to achieve cost containment objectives. This speed reduction will modestly affect data transfer but will more significantly impair interactive network communications. Activities associated with remote sensing, remote data sources and historical data will increase during FY95 as computer and communication access is fully implemented.

2.4. Remote sensing data: This effort will continue to provide Advanced Very High Resolution Radiometry (AVHRR) for sea surface temperature (SST) and acquire Sea viewing Wide Field of View Sensor (SeaWiFS) images for ocean color data. There are three subprojects that will be ongoing: 1) Downlink and archive, providing for data collection from the satellites; 2) SEA data product, reviewing available images for use in SEA; and 3) Distribution, adding the image data to online SEA databases. This subproject will be conducted by Dr. David Eslinger in collaboration with the Geophysical Institute. To realize cost containment objectives, a realtime SeaWiFS license will not be purchased; hence data will not be distributed within SEA in near realtime but rather with the two week delay imposed by proprietary restrictions. Further, remote sensing data services cannot be supported for the full twelve months.

2.5. Remote data sources: These are data sources for current data other than SEA data and satellite data, including detailed meteorological data. In FY95, meteorological data has increased significance in support of the development of the ocean circulation model.

2.6 Historical data: The objectives of this subproject are to (1) assemble a digital index of historical data relevant to SEA; (2) establish an off-line (tape) and low-availability on-line (CD-ROM) data base for historical data available in digital form; and (3) select high priority data resources and complete necessary data processing to integrate these data in the SEA database. The primary investigator for this work is Dr. Gary Drew of the National Biological Survey, Anchorage. He will collaborate with Dr. David Eslinger, UAF, to coordinate the historical and near realtime data sets. Progress was made toward these objectives in 1994, but further historical data remains to be collated.

To achieve cost containment objectives, the following tasks have been postponed to FY96: Historic AVHRR satellite imagery will be acquired primarily from the NOAA archive in Washington, D.C. A time-series to date back to 1985 will be constructed over 13 biweekly intervals April 1 through October 15 annually. Imagery will be processed to provide data on temperature (marine and terrestrial) and indices of primary productivity (terrestrial only). These data layers may be integrated with other data sources, e.g. fish returns, marine primary productivity, etc., to identify

interactions between terrestrial and marine ecosystem components in Prince William Sound. Data layers will be transferred to the Prince William Sound Science Center for master archiving and wide area access.

2.7. SEA data tools: This subproject will provide accessibility and utility of the SEA data, models, and forecasts for the SEA investigators and for those using the results of the investigations. These will include browse tools, help tools, and higher level research tools. During FY94, key software infrastructure was brought online. These efforts will increase during FY95 with cost-sharing from the Xidak grant. The Xidak data server incorporates a basic set of data query tools as well as a programming environment. It is designed to interface easily with existing custom SEA software and high end scientific data visualization packages.

3. Descriptive model and interface

This subproject addresses (1) the description of the state of the system given measured data and an incomplete abstract definition or model of the system, and (2) an interface to the data in terms of the system variables. The overall objective is to continue development of an interface to existing data that provides for display, query, and the computation of further variables that are functions of the state of the system.

3.1. Visualization: Visualization interfaces will be developed relating temperature, salinity, ocean currents, number and biomass distribution with respect to volume, size, cohort and sex. The spatial domain of definition for each of these as system variables is the three-dimensional region of Prince William Sound and the North Gulf of Alaska.

3.2. Support for adaptive sampling: Adaptive field sampling strategies require accurate and near real-time information. This subproject will provide (1) near real-time communications; (2) transmission of reduced image format data to the field and decision aid tools for field use; and (3) short term statistical and numerical model forecasts.

4. Numerical models

The work of this subproject is the development of numerical models. The ultimate objective is the capability to understand quantitatively and to simulate the time evolution of processes regulating the populations of pink salmon and Pacific herring in Prince William Sound during their early life stages. Modeling objectives for 1995 are continued development and testing of (1) ocean circulation model; (2) physical-biological model; and (3) model frameworks for observations of feeding, dispersion, mortality, and growth.

4.1. Ocean circulation model: During FY95, Dr. Chris Mooers, RSMAS, will begin implementation of the Mellor ocean circulation model for Prince William Sound. This will provide SEA with a continuously running, three dimensional circulation model driven by atmospheric forcing, tides, river run-off, and remote forcing along open boundaries. The model output will be accessible over the Internet. While it is feasible to consider a first order version of the model running during the middle of FY95, the project schedule is instead for early in FY96. Under this

project schedule the first half of FY95 will be devoted to establishing data bases for boundary conditions and near realtime and climatological forcing. To establish the critical links between the ocean circulation model and observed physical and biological processes from the FY94 field survey, there will be extensive collaboration with Dr. David Salmon (SEA-OCEAN), Dr. Gary Thomas (SEA-FISH), and Dr. David Eslinger. Model development will commence during the second half of FY95.

4.2. **Physical-biological model:** Recent advances in ocean circulation models and their numerical solution have led to efforts to model and simulate the time evolution of planktonic populations in a subsystem. These time evolution models are often called physical-biological models. They are hybrid models combining ocean circulation models with biological models for foraging, natural mortality, regeneration. These models can be extended to include planktivore grazing with the addition of models for the foraging and dispersion of the planktivores. These are the models needed for the river-lake hypothesis. For 1995, this modeling effort will continue at a somewhat curtailed pace so that emphasis can be placed upon the completion of the ocean circulation model, with a significant part of the effort here supporting that collaboration. Dr. David Eslinger, UAF/IMS, will be contracted to conduct this effort, in coordination with the SEA projects for in situ measurements of the phytoplankton population and nutrient concentrations (Peter McRoy and David Eslinger) and zooplankton distribution (Ted Cooney).

4.3. **Nekton ecological processes:** The observed distribution of nekton can be modelled as a response to the present distribution relative to alternative distributions. A simple formulation consists of a "preference" measure for an environmental variable such as temperature, light level, or temperature gradient (thermal front). There is feedback in the case of a predator and its prey both responding to some combined measure of rates of feeding and rates of predator attack. These models will draw upon the collective knowledge of SEA, especially the findings of the SEA-FISH project, regarding the distribution and behavior of specific populations, the interpretation of observed overlapping distributions, and results from field studies of diet and foraging. Dr. Doran Mason, University of Wisconsin Limnology Laboratory, will collaborate with Dr. Vince Patrick, Dr. Gary Thomas and Mark Willette (ADFG) in the development of distribution-feeding-growth models. Dr. Ricardo Nohetto will also collaborate as an expert in numerical methods for the classes of equations used in this project. For FY95 this work will proceed at a somewhat curtailed level in order to focus resources on the completion of the ocean circulation model.

5. Sampling technologies

The search for techniques that will improve the cost efficiency of monitoring and reduce the sparseness of sampling is shared by all projects in SEA. Whereas many new methods fall within the usual boundaries of specific disciplines, others do not. In particular, methods that significantly increase the scale of coverage for a fixed measurement effort often involve the use of nonconventional sensors, signal processing, and inverse methods. In such cases evaluation and initial testing is often easiest from within the multidisciplinary scope of the SEADATA project. Consequently, an ongoing objective of this subproject is the search and review of candidate new technologies. During FY94 the Chelsea, Ltd. Aquashuttle platform equipped with the FOCAL Technologies, Ltd. optical plankton counter was introduced and initial sea trials conducted. The

integration of these devices into the SEA survey plans will continue in FY95. In addition, an implementation plan will be developed, in collaboration with the SEA-FISH project, for the use of the Aquashuttle with high frequency acoustic sensors.

A second subproject for FY94 is a review of the applicability of acoustic tomography at selected sites in Prince William Sound for the autonomous acquisition of nearly continuous, near realtime measurement of sound speed and current velocity along a planar region between fixed buoy stations. This review is being conducted by Dr. C. A. Berenstein. It has received the additional services of Mr. D. Lindsay from July through September 1994, at no-cost to the Trustee Council through National Science Foundation support for Mr. Lindsay. In addition, a no-cost collaborative effort has been initiated with Dr. A. Tolstoy of the Naval Research Laboratory. If the FY94 review is positive, work will continue in FY95 to formulate a cost-effective implementation plan and conduct simulations.

PROJECT IMPLEMENTATION

This proposal is a continuation of FY94 project 94320J, SEA Information Systems and Model Development (SEADATA). The lead agency for the project is the Alaska Department of Fish and Game (ADFG), which, as a Trustee Council agency, receives funding from the US District Court upon approval by the Council. A second agency, the National Biological Survey (NBS), will participate in a collaborative role within the SEADATA project. The work will be conducted cooperatively by a collection of organizations under subcontracts from the University of Alaska Fairbanks (UAF) in accordance with a research service agreement between UAF and ADFG. The participating organizations are:

Prince William Sound Science Center (PWSSC), Principal Investigator and Project Leader: Vince Patrick, PhD. The PWSSC is the home base for several SEA projects and serves as the geographic, strategic and organizational headquarters of the SEADATA effort.

UAF Institute of Marine Science, Principal Investigator: David Eslinger, PhD

Rosenstiel School of Marine and Atmospheric Science (RSMAS), Principal Investigator: Chris Mooers, PhD

Advanced Visualization Laboratory, Principal Investigator: Ravi Kulkarni, PhD

University of Maryland (UMD), Principal Investigator: Carlos Berenstein, PhD

COORDINATION OF INTEGRATED RESEARCH EFFORT

SEADATA is an integral part of the 13 projects comprising the SEA program, which was conceived from the beginning as a multidisciplinary, interagency, collaborative study. An essential aspect of SEADATA is its inherent coordinating role within SEA. By design SEADATA serves as the central aggregator of SEA survey results, providing a common data pathway and a unifying planning mechanism fundamental to execution of a coordinated survey effort.

In addition, the SEADATA project itself is multidisciplinary and multi-institutional in character. Its technology choices draw from a broad interdisciplinary basis to incorporate tools and resources that

are commonplace in one discipline but new in others—visualization software from space physics; data systems from satellite systems and meteorology; modelling capabilities from developments in oil spill management systems; advanced internetworking technologies; and numerical methods from semiconductor design. Such interdisciplinary incorporation of state of the art technology has been possible through development of a collaborative research plan involving scientists from half a dozen academic, government, corporate or private institutions across the USA and Canada. In consequence parts of SEADATA are shared with ongoing research and monitoring activities elsewhere, and the Trustee Council effort benefits from prior and concurrent research and technology investments at other sites.

The goals and objectives described in this project plan are the result of months of close collaboration with citizens of the region served by the study, on-site resource managers, scientists based in the community and at the University of Alaska, and administrators responsible for the oversight of the restoration resources. Close communications will be maintained with all of these parties during execution of the project, through regular reporting and via Internet and dial-in access to SEADATA applications and products. Coordination among the cooperating institutions and research groups will be enhanced by on-site visits, regularly scheduled reports and electronic briefings, and online interactive network conferencing.

FY 95 BUDGET (\$K)

Personnel	3.0
Travel	0.0
Contractual	812.4
Commodities	0.0
Equipment	0.0
Subtotal	815.4
Gen. Admin.	20.8
Total	836.2

Sound Ecosystem Assessment (SEA), An Ecosystem Research Plan for Prince William Sound -- Observational Physical Oceanography in Prince William Sound and the Gulf of Alaska (SEA OCEAN)

Project Number:	95320M
Restoration Category:	Research (continuation of 94320M)
Proposed By:	Prince William Sound Science Center
Lead Agency:	ADFG
Cost FY 95:	\$577,800 (includes \$138,700 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$525,500
Total Cost:	Unknown
Duration:	2-5 years
Geographic Area:	Prince William Sound and north Gulf of Alaska
Injured Resource/Service:	Multiple resources

INTRODUCTION

The Sound Ecosystem Assessment program (SEA) evaluates changes occurring in the Prince William Sound (PWS) ecosystem in the context of groups of interacting species. The knowledge gained by implementing SEA is vital to determining the feasibility of, and the approach to, restoring many resources and services injured by EVOS. Resources addressed by SEA include pink salmon, herring, and the principal species interacting with these fishes. These pelagic organisms support a host of birds and mammals, some which have also been described as injured species. Services addressed include subsistence, commercial fishing, recreation and tourism, and passive use. While SEA is primarily a monitoring and research activity, this program will also provide support for other EVOS Trustee Council programs (i.e., informing management to promote a healthy ecosystem, increasing public information about the state of the ecosystem). Plans for SEA were developed with the encouragement and support of the EVOS Trustee Council to provide an understanding of important ecological influences on injured resources and services. The initial phase of SEA was funded during the last half of FY 1994.

NEED FOR THE PROJECT

The Sound Ecosystem Assessment (SEA) plan provides a framework to improve our predictive capabilities of key animal population abundance in Prince William Sound (PWS). In order to formulate a responsible and effective strategy for the restoration and recovery of an injured resource or service, it is critical to understand how each component of the system functions in relation to the entire ecosystem. The SEA Plan broadly focuses on the recovery of the ecosystem as well as individual components. Since climate in the PWS region is a major controlling factor on biological populations, it is necessary to understand the linkages between the physical environment and the living resources. The Physical Oceanography project (SEA OCEAN) will collect and analyze data fundamental to a better understanding of the natural variability in Prince William Sound. A knowledge of the prevailing climatic conditions and how they act to constrain biological populations in the *Exxon Valdez* Oil Spill (EVOS) impacted region is a major goal of this project.

An understanding of how to best restore resources damaged by EVOS hinges upon knowledge of both how the PWS ecosystem functions naturally and how it functions under stresses induced by human beings, such as the EVOS. In order to understand how perturbations such as EVOS and the effects of salmon hatcheries propagate their effects through the ecosystem, we must determine the natural variability of the ecosystem. The EVOS Trustee Council has adopted an ecosystem approach to the restoration of injured resources and has initiated ecosystem level studies aimed at understanding how the PWS ecosystem functions. This project is a continuation of the ecosystem level studies that are aimed at guiding restoration efforts. In addition, at recent restoration workshops held by the Trustee Council, it was agreed that an essential element of all restoration research and monitoring projects is a study aimed at characterizing the physical environment in terms of oceanography and meteorology. Therefore, the physical oceanography project is a cornerstone of the entire suite of marine ecosystem level studies. It is essential for placing the PWS ecosystem within the broader context of the climatic factors that constrain both its structure and function.

Pacific herring and pinks salmon, two of the most important commercial and ecological species in PWS are shown to be injured and not recovering. Environmental factors and physical ocean conditions are critical in controlling the juvenile growth, mortality and ultimate recruitment as adults of these two species. The availability of forage for salmon, herring and their predators varies greatly in PWS, as do the changes in the physical and chemical oceanographic environment. The transport of larval salmon and herring is influenced by wind and current-driven processes and their availability to predators is a function of those processes. The growth and survival of these two species are strongly controlled by fluctuations in physical conditions. A better understanding of the physical environment and ecosystem through the study of the physical oceanographic components is necessary to determine protocols for restoration and recovery of these fishes and related species. Recovery of these fishes is, in turn, crucial to the restoration of the species which feed upon them.

Major hypotheses in the SEA program include the idea that the physical environment of PWS and the Gulf of Alaska (GOA) is the major determinant of natural variability in the ecosystem.

In particular, changes in the large scale advective regime in PWS are thought to constrain growth and survival of juvenile pink salmon through both differential availability of important food resources (calanoid copepods) and a prey switching mechanism by which presence or absence of these resources causes potential pink salmon predators to feed more heavily on either pink salmon or copepods. The elucidation of the physical oceanographic structure of PWS, and its space/time variability, is critical to understanding how the ecology of the region changes in response to natural perturbations such as ENSO phenomena and large scale long term temperature fluctuations associated with the 18.6 year nodal tide. This project will characterize and monitor major physical processes that constrain the ecology of pink salmon, their predators, and their prey in PWS. Information concerning the origin, modifications, and fate of water masses that constitute both the surface and deep waters of PWS and determine their biology will be obtained in PWS/GOA. Large scale physical oceanographic measurements will consist of temperature, salinity, and ocean currents (derived density and baroclinic ocean currents) obtained from conductivity/temperature/depth and acoustic doppler recording instruments. Meteorological measurements will include air temperature, precipitation, wind speed and direction and derived products that relate atmospheric forcing to oceanic structure, properties and circulation. Fine scale oceanographic measurements will include determination of horizontal and vertical physical structures (e.g. thermocline, pycnocline, fronts, eddies, tidal rips, shear zones). This study will be closely coordinated with all components of SEA. In particular, both chemical (silicate, phosphate, nitrate, oxygen) and biological data (phytoplankton, zooplankton, ichthyoplankton) will be used as physical oceanographic tracer fields in the determination of how physical processes in PWS act to control the fluctuations of ecological populations. In addition, measurements made in the observational physical oceanography program will be useful in other EVOS Trustee Council funded research efforts aimed at understanding interactions between other species and their environment.

PROJECT DESIGN

A. Objectives

1. Determine the space/time variability of atmospheric and oceanic processes and structures within PWS and the GOA. Atmospheric processes of interest will include winds, precipitation and temperature, while the focus in the ocean will be on currents, fronts, eddies, tidal rips, thermocline, halocline, and changes in properties (both physical and chemical) of both the surface and deep waters.
2. Determine the relationships and interactions between atmospheric forcing (winds, storms, long term temperature changes) and wind and buoyancy driven ocean currents in PWS/GOA.
3. Determine how the relationships described in 2) act to retain or disperse major food resources for ecologically important species within PWS.

4. Ascertain the large and fine scale oceanographic structure and the major climatic cycles (ENSO, nodal tide) and events (e.g storms) that affect PWS/GOA within the context of the space/time distributions and changes in abundance of important populations in these regions.

B. Methods

Large Scale Physical Oceanography in Conjunction with the River/Lake Hypothesis

The large scale measurements made in the SEA physical oceanography program are crucial to testing the validity of the river-lake hypothesis. Baseline information concerning the water masses that constitute the externally advected surface and deep waters of Prince William Sound will be obtained from transects in the Gulf of Alaska. Local freshwater input to PWS will be estimated from stream measurements and a hydrologic model. These oceanographic transects will cut across the Alaska Coastal Current (ACC) and the deep shelf waters in the northern Gulf of Alaska. Measurements taken during the 1994 field season (as of July) include CTD, zooplankton and chemical sampling. Physical information will consist of temperature, salinity, density profiles obtained from conductivity/temperature/depth (CTD) profilers, ocean current velocities obtained from acoustic doppler current profiler (ADCP) measurements and (geopotential) dynamic heights calculated from CTD data. ADCP backscatter will also be experimented with in SEA investigations to ascertain its effectiveness in augmenting biological (i.e. net capture) measurements of zooplankton distribution and abundance. Chemical signatures (nitrate, silicate, and phosphate, possibly tritium or other tracers) of ACC and shelf derived waters will be obtained from Niskin bottle samples mounted with the CTD on a rosette. Conservative nutrient based tracers will be computed from the nutrient distributions because of their utility in ascertaining distinctions between water masses. These tracers will be particularly useful for discerning deep water characteristics. In addition, the biota found in ACC waters are distinct from those found on the deep shelf (i.e. neritic versus oceanic) and will be used as tracers to further discern differences between water masses that enter the Sound via Hinchinbrook Entrance (HE).

Transects across HE, southwestern PWS, Montague Strait (MS), and regions of the central Sound will be made to determine the advective regime within PWS. Sampling will encompass the entire water column in shallow regions or down to about 775 m in the deeper areas of the Sound. This will allow for the determination of both surface water flushing patterns (and rates) and deep water renewal processes in the Sound, as well as the abundance of associated deep and near surface zooplankton assemblages. Sampling will include CTD, ADCP, and chemical measurements (Zooplankton sampling techniques are described in the zooplankton sampling program, *SEA-ZOO: The Role of Zooplankton in the Prince William Sound Ecosystem, 95320H*). Ocean current sampling will be conducted over the course of several tidal cycles in order to determine the relative contribution of tidal currents to the net flow regime. In the southwestern Sound, physical and zooplankton sampling will be conducted for all passages that drain out of PWS. ADCP and CTD transects will be run across Elrington and LaTouche Passages as well as across Port Bainbridge to include (presumably) outflow from Bainbridge and Prince of Wales Passages. Further north, transects will be run across Knight Island Passage and MS to determine the relative contributions from these area. Physical and zooplankton sampling in the

southwestern Sound will be conducted in close coordination with predator and juvenile salmon sampling. Time series of oceanographic parameters begun in 1990 during the CFOS program and the 1994 SEA field season will be continued during the SEA 1995 program. These time series are extremely valuable in that they are the only ones of this resolution and duration for PWS.

Four CTD instruments will be deployed on vessels in PWS. One CTD will be towed on an underwater towing platform in western PWS, that is mounted with a fluorometer, optical plankton counter and a dissolved oxygen sensor. One CTD is mounted on a rosette for use in conjunction with chemical oceanographic sampling. The two other CTDs will be used for fine scale surveys in conjunction with salmon predation and growth studies in both the northwestern and southwestern Sound. The fine scale sampling is described below in a separate section. Initially one ADCP will be deployed aboard a vessel that will sample in western PWS, concentrating on the region of outflow to the GOA (which includes MS). This vessel will also work frequently in HE and the adjacent GOA to characterize flow in the ACC, determine how much of this flow is deflected into PWS, and determine the shelf water contribution into PWS. Chemical and biological sampling will provide data to assist in determining the advective regime and its source waters in the Sound in both time and space. Station spacing along transect lines will be approximately 2 nautical miles. A second ADCP will be utilized in a moored deployment in the HE region of PWS. A CTD will also be attached near the bottom of the mooring for characterizing influxes of bottom water from the GOA into PWS. The moored deployment will begin in FY1994 and will be used over the winter months to determine the flow field in response to intense atmospheric forcing, and the presence/absence of biological scattering layers. The period of deployment will be four to six months, after which the data will be retrieved and the instruments redeployed for a similar duration. The feasibility of real time data links from the mooring to Cordova is being investigated during 1994. The principal and most intense sampling periods for CTD, ADCP and chemical measurements will occur from April through July, although measurements will also be made in the fall and winter months in order to determine how the regional oceanography and meteorology fits into the larger scale variability (i.e. interannual variability). The months of April and May will be sampled most intensively in HE, the GOA, MS and the central Sound, since the correlations observed between zooplankton abundance and atmospheric forcing are strongest during these months.

Meteorological data will be obtained in a nearly continuous fashion from the CFOS meteorological buoy moored within PWS. This buoy is also equipped with oceanographic sensors (fluorometer, thermistor chain). Satellite tracked drifting buoys will also be deployed in PWS and the ACC periodically in order to track surface ocean circulation patterns and their evolution throughout the year.

Vessels of opportunity will also be employed in obtaining large scale physical and biological oceanographic data in the SEA program. During FY 1994, a thermosalinograph was installed on the tanker T/V *Keystone Tonsina* as part of the SEA physical oceanography program. This vessel transits PWS and the Gulf of Alaska four times a year and will provide continuous measurements of temperature and salinity through these regions. In FY 94 the U. S. Coast Guard allowed us to use the cutter *Sweetbrier* for deploying oceanographic equipment, including

a towed ADCP and towed CTD system. This cooperative arrangement is envisioned to continue in FY95, as the Coast Guard is interested in the results of the research.

In addition to directly measured oceanographic and atmospheric variables, SEA physical oceanography will use prepared data products. In particular these will include satellite imagery (e.g. AVHRR, CZCS, and possibly SAR) when available, as well as large scale atmospheric pressure and downwelling index data for the North Pacific (available from Fleet Numerical Oceanographic Center, Monterey, CA). These data have been utilized in initial analyses of relationships between zooplankton and atmospheric/oceanic forcing. Large scale North Pacific sea surface temperature fields (available from Scripps Institution of Oceanography, La Jolla, CA) have been obtained on a periodic basis for updates and computations of anomalies over large regions of the North Pacific that have been identified in empirical orthogonal function analyses.

Fine Scale Physical Oceanography

Measurements of mesoscale and fine scale oceanographic features are essential for the thorough characterization of environmental conditions that constrain the growth and survival of the species being studied (pink salmon, their predators and their prey) in the western Sound during the 1995 SEA program. Closely spaced CTD measurements will be made in conjunction with ADCP sampling to elucidate the fine scale physical structure (e.g. thermocline, pycnocline, fronts, eddies, shear zones) within the western regions of the Sound, particularly in relation to the distributions of phytoplankton, zooplankton, juvenile salmon and salmon predators such as juvenile pollock and cod. These measurements will address physical conditions that characterize diel vertical migrations of these species. Two Seabird Seacat CTDs will be used in the characterization of fine scale structures. These instruments are highly portable and self contained and will be transferred back and forth between the larger seiners for offshore and nearshore work and the small skiffs for inshore measurements. The ADCP will principally be used for characterizing the large scale velocity field in western PWS, but will occasionally be deployed aboard the seiner or a small skiff for nearshore work, particularly in relation to characterization of velocity fields related to small scale frontal structures and nearshore tidal rips.

Integration of Large and Small Scale Physical Oceanography

The migratory pathway that the salmon utilize during their outmigration from the Sound will be characterized in terms of its physical (and biological) oceanographic structure. The problem of whether these animals utilize specific physical conditions and oceanographic structures during their outmigration will be addressed. This will be accomplished through the integration of large and small scale horizontal and vertical measurements made in western PWS. The sampling frequency will be highest during the months of April through June, with less frequent sampling in July and August. Horizontal spatial sampling scales will range from meters to kilometers and vertical scales will range from meters to hundreds of meters.

Large and small scale physical, chemical and biological data will also be assimilated into numerical models of the deep and surface circulation in the GOA and PWS. The modeling efforts are described under a separate project (Information Systems and Modeling).

Fall and Winter Oceanographic Measurement Programs

Winter surveys of both large and small scale physical properties and structures within the PWS/GOA region will be conducted in order to fit observed environmental conditions within the context of the very substantial annual and interannual variability that governs the meteorology and oceanography of the North Pacific. In particular the physical transitions from El Niño to La Niña conditions will be documented in order to assess and predict changes in the structure and distribution of animal and phytoplankton assemblages in response to these environmental regime shifts. The nature and phasing of large scale long term temperature changes in PWS in relation to the (18.6 year) nodal tide will also be addressed.

PROJECT IMPLEMENTATION

This PWS Science Center will be the lead organization in the implementation of this project. Oceanographic sampling will take place principally on vessels chartered by ADFG. The U. S. Coast Guard has also agreed to provide vessel time for SEA oceanographic sampling during 1994. Opportunities for continued sampling aboard Coast Guard vessels during FY95 are being sought out at this time.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The SEA physical oceanography program will be closely coordinated with other components of the SEA field and modeling studies. All of the physical oceanographic field surveys will be conducted in conjunction with a combination of chemical oceanographic and phytoplankton sampling, zooplankton assessment and capture, and nekton (both juvenile and adult fish) assessment and capture. Also, by arrangement between the Alaska Department of Fish and Game and the National Biological Survey, marine mammal and bird observers will be onboard some of the sampling vessels in coordination with projects 94102 (murrelet prey), 94159 (marine bird surveys) and 94173 (pigeon guillemot). The SEA program will be integrated with project 94163 (forage fish study) whenever possible and appropriate. The SEA program will be coordinated with ADFG projects that relate to pink salmon and herring but were underway before the initiation of SEA planning efforts. These include projects 94166 (herring spawn deposition survey), 94184, 94185 (coded wire tagging studies), 94187 (otolith marking), and 94191 (oil related egg and alevin mortalities). In addition, USFWS and NMFS personnel have been contacted to coordinate efforts undertaken in the NOAA forage fish study in PWS. In summary, we will work with all personnel who have an interest in the oceanography of the region for use in their research, and to strengthen the interdisciplinary nature of the research proposed to be continued from the FY94 field season.

A cooperative investigation involving the chemistry of mussel tissue, seawater and sediments has been initiated during FFY94 by the Auke Bay Laboratory (NOAA) and the PWS Science Center. The investigation stems from NOAA's ongoing mussel watch program, but has been endorsed by the SEA program because the results of the mussel sampling program are pertinent to the hypotheses generated for the initial phase of SEA. It is envisioned that the

mussel collection and interpretation can be broadened as part of the SEA field studies. SEA investigators could provide support for data collection within the Sound during periods when field sampling is underway. SEA investigators collected samples for Auke Bay during FY94.

FY 95 BUDGET (\$K)

Personnel	3.0
Travel	0.0
Contractual	560.4
Commodities	0.0
Equipment	0.0
Subtotal	563.4
Gen. Admin.	14.4
Total	577.8

Sound Ecosystem Assessment (SEA), An Ecosystem Research Plan for Prince William Sound -- Nearshore Fish (SEA-FISH)

Project Number:	95320N
Restoration Category:	Research (continuation of 94320N)
Proposed By:	Prince William Sound Science Center
Lead Trustee Agency:	ADFG
Cost FY 95:	\$635,200
Cost FY 96:	\$635,200
Total Cost:	Unknown
Duration:	Unknown
Geographic Area:	Prince William Sound and north Gulf of Alaska
Injured Resource/Service:	Pink salmon and Pacific herring

INTRODUCTION

Accurate prediction of abundance is a prerequisite to efficient restoration, rehabilitation or compensation of anthropogenic damages, such as oil spill damage, to key animal populations. For example, fisheries science has used hatchery practices on a widespread basis to restore, rehabilitate, and compensate for overfishing, habitat destruction and industrial damages with little knowledge of ecosystem impacts. Recently, hatchery practices have been critically reviewed and their benefits have become highly controversial. Similar controversies exist over shoreline oil cleanup practices, habitat modification programs, and animal rehabilitation and recovery centers. Restoration practices will remain controversial until our understanding of ecosystem level processes allow for the development of predictive models. Predictive models are the tool for determining the outcome of anthropogenic events (oil spills, habitat loss, etc.) and restoration of damages.

The first step in developing tools for the prediction of population structure and change in Prince William Sound is to develop a better understanding of the marine ecosystem. Unfortunately, the dynamics of marine ecosystems is poorly understood making accurate predictions of change in marine animal populations impossible. The dynamics in composition and production of the plankton/nekton assemblage that resides in PWS is no exception, despite the intensive single population assessments after the *Exxon Valdez* oil spill. For instance, there are some long term databases on the harvests of key commercial fish populations, yet little is

known about how fluctuations of co-occurring populations (prey and predators) affect the abundance of the key populations, or how change in prey and predators populations are affected by climate-driven warming and cooling processes.

In response to the lack of ecosystem and species-specific knowledge, SEA advanced several ecosystem level hypotheses to explain the physical and biological dynamics of PWS and potential impact on previously identified sensitive populations, pink salmon and herring. The hypotheses emphasize the potential role of climate driven circulation patterns on the abundance and distribution of macrozooplankton food of juvenile fish (the lake river hypothesis), how changes in water circulation patterns may effect predator and prey dynamics (prey switching hypothesis) and the role of winter rearing habitat on the survival of juvenile herring (overwintering hypothesis). Evidence exists suggesting that climate driven events are important for understanding survival of many fish populations.

Pearcy has shown a positive correlation exists between the intensity and frequency of upwelling events (climate-driven oceanographic and atmospheric processes) and salmon survival along the Oregon and Washington coast. Cooney has shown that the critical food sources for larval and juvenile fishes in PWS, the large oceanic calanoids, undergo annual and seasonal fluctuations in abundance, and proposed that climate-driven ocean currents cause major fluctuations in the calanoid abundance. Recently, low survival of salmon and herring has been attributed to shifts in predator populations into the La Perouse Bank during El Nino years. Furthermore, the lunar nodal hypothesis suggests an 18.6 year cycle in climate driven warming and cooling of the eastern North Pacific) that may affect prey and predator populations, which influence fish production. Thus, it is likely that climate driven fluctuations in ocean processes influences prey and predator abundance and distribution of salmon and herring survival in PWS.

The scientific goals of the Sound Ecosystem Assessment Plan (SEA) are to:

1. Improve our understanding of the ecosystem level processes that determine the abundance and interaction of key animal populations in Prince William Sound (PWS), focusing initially on pink salmon and Pacific herring, their predators and prey, and how they respond to climate driven physical processes.
2. Develop and apply new measurement technologies for accurately and synchronously assessing ecosystem variables (temperature, currents, prey, predators. etc.) that affect the survival of the key animal and co-occurring populations of prey and predators.
3. Incorporate the new and improved information into numerical models to predict the abundance of key animal populations.
4. Using new predictive capability, determine best protocols to restore, rehabilitate or compensate for anthropogenic damages to key animal populations.

Knowledge of the effects of toxic chemicals, such as hydrocarbons from an oil spill; on individual organisms is extremely useful to characterize the qualitative nature of impact that

occurs with the introduction of a toxicant into the environment. However, to determine the quantitative impacts, understanding of ecosystem-level interactions is essential. Westman presented four approaches that are used to study ecosystem level impact. They are listed here by the strength of the scientific method and logistic difficulty: (1) in situ, experimental manipulations of the natural ecosystem, (2) in situ, synecological studies of natural ecosystems along disturbance gradients, (3) in vivo, microcosm studies, and (4) in vitro, data assimilation into computer models of natural ecosystems, which can be subjected to disturbance by simulations.

The SEA program is offered a unique opportunity to take an ecosystem manipulation approach because of the operations of the PWS hatcheries, which release over 700 million salmon fry annually. For example, pilot field studies of predator response to hatchery releases were conducted using underwater acoustics at the Sawmill Bay, Esther and Cannery Creek facilities in 1992 and 1993. A major survey of the outmigration corridor for pink salmon is ongoing in the western Prince William Sound. Thus, the initial implementation of the SEA program is using hatchery releases as the experimental manipulation of the trophic structure supporting pink salmon survival. Synecological studies and simulation models of the ecosystem along natural and gradients via poststratification of field measurement data will be possible for pink salmon and Pacific herring.

SEA's conceptual framework is similar to GLOBEC, a National Science Foundation sponsored program titled Global Ocean Ecosystems Dynamics. The PWS pink salmon and herring populations fluctuate in abundance as the cumulative result of three processes: birth, mortality and transport. A simplified description of the population growth rate is:

$$dN/dt = \text{Birth rate} - \text{Death} - \text{Immigration} + \text{Emigration}$$

where,

- *Birth* is influenced by the numbers and condition of the parents and the environment at spawning,
- *Death* is influenced by the condition of the eggs or fish and the environment, which is primarily a function of growth and predator densities,
- growth is influenced by the abundance, distribution and quality of prey, ambient physical conditions, maintenance and activity levels, interactions with predators and competitors, and condition of the fish, and is often expressed as consumption - (Respiration + Waste Losses), which are functions of food quantity and quality, competition, and condition of the fish and environment.
- *Immigration* is the transport (as a behavioral or physical advection process) or straying (behavioral or random diffusion) of fish into the population, which is primarily a function of the physical environment and the behavior of the fish,
- *Emigration* is the transport or straying of fish out of the population.

The importance of ocean ecosystem state and the condition of the fish (population state) is emphasized since physical and physiology/behavior conditions affect each variable and their subvariables in time and space. The importance of biological ecosystem state is emphasized

fewer times above, but can dominate dN/dt . SEA's large scale surveys with nested fine scale examination of mechanistic processes using quasicontinuous measurement technologies are essential to reliably describe physical and biological state.

To understand anthropogenic or natural effects on the production of pink salmon and herring, SEA developed several hypotheses. The primary hypotheses of the SEA program concerns flushing of prey from the Sound (the river-lake hypothesis) and the switching by predators to larval fish when the macrozooplankton are not abundant (the prey switching hypothesis). These are coupled hypotheses because when the flushing of PWS is high, the macrozooplankton prey is low, which causes larval and juvenile fish predation to be high. Since flushing is positively correlated with storms, and stormy years are cold years, the physical growth conditions (temperature and currents) are also poor when there is limited prey. Preliminary results this year suggest that prey switching is a seasonal event, and that the duration and intensity of this phenomenon is an object to quantify with respect to river or lake years.

Many researchers have proposed that multiannual, climate-driven cycles of three, five, seven, 14, 18.6 years have a dominant influence on marine productivity and fish recruitment. Shifts in predator populations as a response to climatic events have also been shown to have pronounced impacts on key marine fish populations. Preliminary results this year suggest that walleye pollock is a primary predator on juvenile fishes in the Sound. The influence of climate changes, such as those induced by EL Nino and La Nina events, on the walleye pollock distribution needs to be examined with respect to river or lake years.

Given the likelihood that natural, climate-driven cycles have a dominant influence on marine fish recruitment, the description of these phenomenon are logical steps in the future testing of the river-lake and prey-switching hypotheses which is the prerequisite to evaluation of anthropogenic influences such as oil spills, hatchery practices, commercial fishing, and the restoration of damage.

Using the North Atlantic program as a guide, SEA will be implemented by three interdisciplinary efforts: (1) large and fine scale, field studies on physical oceanography and plankton/nekton ecology, (2) applications and development of new technologies, and (3) mathematical modeling. The application of acoustic and optical technologies in the large and fine scale field studies, physical oceanography and the mathematical modeling are included in proposals submitted by the PWS Science Center.

To solve the sampling problems of scale and time, SEA projects have restricted their field sampling efforts to the timing and route of the outmigrating juvenile pink salmon and the nearshore rearing areas of Pacific herring. In agreement with GLOBEC, SEA OCEAN and SEAFISH incorporate optical and acoustic technologies that provide quasicontinuous data necessary for describing spatial and temporal characteristics of physical and biological patchiness along migratory routes. Acoustic and optical targets will be subsampled with a variety of nets and other seatruthing capabilities to collect biological information. The seatruthing is a principal task of other cooperating SEA projects supervised by ADFG and UAFIMS and is the primary activity where commercial fishermen will contribute their expertise

to the scientific investigation.

Large scale sampling will define potential prey and predator concentrations (distributions) along the offshore route of the pink salmon outmigration and in the juvenile Pacific herring rearing areas. This information will be collected simultaneously with the physical and biological oceanography to evaluate specific climate-driven hypotheses. The fine scale sampling will define the population and individual-level interactions between predators and prey and how these interactions may be influenced by dominant physical processes, such as tidal fluctuation.

Implementation of the SEA plan is via a team effort between physicists, biologists, computer scientists, communication specialists, fishermen, government and private organizations. The team approach serves several purposes. First, a diverse team is essential because of the wide variety of technical expertise needed to acquire and analyses ecosystem data (physical, biological, technologists, etc.). Second, a team approach that integrates the public, the government and private organizations into the planning process is essential to develop a unifying ecosystem plan. Protection of valuable renewable resources within an ecosystem requires a unifying plan to establish goals that are developed by, and therefore acceptable to, the public. Despite huge government investments, regulatory agency mandates and goals programming efforts have failed to meet the public's expectations of sustaining valuable renewable resources that support local economies and quality of life.

A unifying ecosystem plan that integrates agency, private and public concerns into publicly accepted goals can be used for several purposes. Although the SEA plan is not a complete ecosystem plan it has allowed us to prioritize research and monitoring data collection efforts for the purposes of developing better predictive capability. As pointed out earlier, this is a prerequisite for establishing non-controversial restoration plans. In the same sense, the expansion of the plan to a complete ecosystem level will allow for regulatory agencies to prioritize what needs to be done and better define cooperative roles in ecosystem management. Allowing public and private roles in the ecosystem planning efforts will create a partnership between government agencies, academic scientists, the public and the private user groups that is necessary for establishing sustainable use practices for renewable natural resources.

NEED FOR THE PROJECT

The fundamental research needed to develop an improved understanding of the ecosystem level processes in Prince William Sound is defined in SEA as the development of integrated physical and biological state models. Paramount to the physical state model is the description of a climate-driven, tidal/temperature-influenced, current model of the Sound. This model is being developed by the SEAOCEAN project. Paramount to the biological state model is a description model of a plankton-nekton density distribution model for the Sound and how it relates to the physical state model to determine climate-driven biological response. This descriptive model is being developed by SEAFISH project in collaboration with the pink salmon and herring capture projects (ADFG), and the zooplankton capture projects (UAFIMS) who provide the biological data on acoustic target distributions. The integration of the acoustic and

biological data will allow interpreting biological response of the assemblage to climate driven processes by key and co-occurring populations. The integration of the physical and biological state models are necessary to test river lake and prey switching hypotheses. These descriptive models are being converted into numerical predictive models by the SEADATA project, focusing primarily on improving the predictions of two selected species, pink salmon and herring. By virtue of its quantitative nature, the SEADATA project is responsible for making improvements to measurement technologies for improving data quantity and quality.

PROJECT DESIGN

A. Objectives

SEAFISH will provide large and fine scale information on the abundance and distribution of macrozooplankton and nekton (pink salmon fry, juvenile herring, potential predators, potential competitors) to the SEA model. New information emerging from SEAFISH will contribute to a comprehensive data base for the fisheries of Prince William Sound. This information will serve the needs of the region for more informed management, enhancement, and mandated restoration activities. As a project within the multidisciplinary, integrated SEA program, SEAFISH will achieve the following objectives:

1. Acoustically describe the macrozooplankton density and distribution with high frequency sonars (HFS) and an optical plankton counter (OPC).
2. Combine acoustic, plankton net catch and oceanographic data to evaluate the river-lake and prey switching hypotheses.
3. Develop protocols for directing net sampling by UAFIMS researchers.
4. Acoustically describe the nekton density and distribution with digital multibeam beam sonars (DMBS).
5. Combine acoustic, nekton catch and oceanographic data to evaluate the prey switching hypothesis.
6. Develop protocols for directing net sampling by ADFG researchers.
7. In collaboration with other EVOS researchers, integrate the SEAFISH research project with research on sea birds, mammals, other fishes, terrestrial ecology and ecotoxicology.

B. Methods

The following methods will be used to address the specific objectives.

Objective 1 - macrozooplankton

The large scale density and distribution on density of the macrozooplankton will be measured using a three-frequency, digital, scientific echosounders (HFS) and an optical plankton counter (OPC). The frequencies chosen are 420, 720 and 1000 kHz. All transducers will be of dual or split beam configurations to obtain both integration of acoustic backscatter and determine target strengths. These frequencies will be supplemented with either 70 or 120 Khz digital split beam sonars (DMBS) to collect synchronous measures of nekton targets. Initially, the HFS will be deployed on a towfin and the OPC on an aquashuttle. The feasibility of deploying the HFS on the aquashuttle is being investigated. The aquashuttle deployment allows for yoyo towing, or high resolution measurement of the upper water column. The DMBS and HFS system will be deployed from the trawler and work the large scale western Sound transects.

The initial processing of DMBS, HFS and OPC data will occur in real time using BIOMAP software on a DOS platform aboard the sampling vessel. Post-processing, analysis, and visualization of the data will occur in the laboratory on UNIX workstations using software developed in house using Interactive Data Language (IDL), Advanced Visual Systems (AVS) and ARCINFO.

Objective 2 - nekton

Large scale measurements of fish distributions will be made using 70 and 120 Khz digital split beam sonars. Initially, the program will use a 120 kHz dual beam, and shift to 70 kHz digital dual/split beam systems as they become available. Transducers will be mounted on a stable platform and towed along the side of survey vessels at speeds of about 6 knots. Sampling will occur in western PWS between April and August and through the entire Sound all year for herring. As above, the preprocessing of data will occur in real time on a DOS platform. Post-processing, data analysis and visualization will occur in the laboratory using software developed from IDL, AVS and ARCINFO. The feasibility of using high resolution video, panchromatic, compact airborne, spectrographic, imager and or other aerial optical techniques to map nearshore concentrations of fishes and to use such information to stratify fine scale survey efforts for nearshore herring assessment will be investigated.

Objective 3 - birds, mammals, other fish

SEAFISH will collaborate with other EVOS researchers and integrate with research on sea birds, mammals, and other fishes. The large scale distribution and information on density of the macrozooplankton and fishes, and oceanographic data (current velocities and temperature), will provide valuable information to bird and mammal researchers. Bird and mammal observers will use visual, photographic, and video measurement techniques on the western Sound vessel and aerial transects.

Synoptic sampling of both the biological and physical characteristics of the water column and samplers that operate on quasi-continuous, spatial and temporal scales are essential if SEA is to link small scale process measurements to population and ecosystem parameters. In response to this, the three core SEA projects, SEAOCEAN, SEAFISH and SEADATA incorporate the necessary acoustical, optical, measurement and computer intensive analytical and communication tools. Recognizing the rapid evolution of technologies, a small component of each SEA project will be the research and development of new hardware and software.

C. Schedule

The SEA field program will use the conceptual experimental design of GLOBEC, which involves the nesting of fine scale measurement programs within large scale ecosystem monitoring efforts. Ocean state and macrozooplankton prey monitoring will require large scale surveys in the: (1) eastern Sound, (2) western Sound, and (3) coastal buoyancy current, and fine scale studies in the: (4) Hinchinbrook Entrance, and (5) Montague Straits. Monitoring will require large scale and fine scale surveys in the western Sound, which is the primary migration route of pink salmon and Pacific herring.

Western Sound and Montague Straits surveys will be the primary survey areas for the 1994-95 field seasons. Surveys in these areas will commence in April and run through July during the pink salmon outmigration. As Pacific herring spawning and rearing surveys are initiated, additional study areas in the eastern Sound, coastal buoyancy current and Hinchinbrook Entrance may be added. These surveys will be conducted between the September onshore migration of adult herring into the Sound and the spring spawning season.

D. Technical Support

SEAFISH is a multidisciplinary study that will rely on: (1) cooperative, model development to assist in sampling design, data analysis and interpretation, (2) shared vessel and facilities for data collection and logistical support, (3) data sharing with the agency and university principal investigators, and (3) remote sensing with acoustical and optical technologies. The cooperative model development will be closest between Dr. Salmon (SEAOCEAN) and Dr. Patrick (SEADATA). Interaction between SEAFISH and SEAOCEAN will be to develop the descriptive model of biological response to physical forcing functions (current velocity and direction). The descriptive model will serve as a guide for the development of numerical models under the SEADATA project that allow for prediction.

The majority of acoustic data that are collected will be on ADFG fishing vessel charters while working synchronously with net sampling of nekton (ADFG) and plankton (UAFIMS). Data sharing with these cooperative projects are essential in interpreting biological response to physical forcing phenomenon by key or co-occurring populations. Dr. Cooney (UAFIMS) is the primary technical support for acquiring macrozooplankton biological information and Mark Willette, Evelyn Brown/Bigg and John Wilcox (ADFG) for nekton biological information. SEAFISH will rely heavily on the existing knowledge and skills of commercial fishers for the capture fishes that are observed acoustically. Prince William Sound Aquaculture salmon

hatcheries in the region will provide logistic support for SEAFISH field crews (communications, gas, supplies, etc.) and the hatchery releases of pink salmon will be treated as experimental manipulation of the nearshore Sound ecosystem.

E. Location

This project will be conducted in Prince William Sound and the adjacent waters of the North Gulf of Alaska.

PROJECT IMPLEMENTATION

The SEAFISH project is funded by a subcontract to the Prince William Sound Science Center from the University of Alaska, Institute of Marine Sciences in accordance to a research service agreement (RSA) with the Alaska Department of Fish and Game. As a Trustee Council agency, the Alaska Department of Fish and Game receives funding from the U.S. District court when approval is issued by the Council to fund this project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The SEAFISH project is a coordinated ecosystem research effort between state and federal agencies, universities, private corporations, Alaska Natives and the public. The coordination and communication between cooperating parties will be facilitated by wide and local area networks using SHOWMe software.

FY 95 BUDGET (\$K)

Personnel	3.0
Travel	0.0
Contractual	616.4
Commodities	0.0
Equipment	0.0
Subtotal	619.4
Gen. Admin.	15.8
Total	635.2

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Sound Ecosystem Assessment (SEA), An Ecosystem Research Plan for Prince William Sound--Avian Predation on Herring Spawn

Project Number:	95320Q
Restoration Category:	Research (continuation of 94320Q)
Proposed By:	USFS
Lead Trustee Agency:	ADFG
Cooperating Agencies:	DOI, NOAA
Cost FY 95:	\$99,000 (includes \$23,100 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$30,600
Total Cost:	\$129,600
Duration:	2 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring

INTRODUCTION

Pacific herring (*Clupea pallasii*) has been identified as a resource injured by the *Exxon Valdez* oil spill. Studies conducted from 1989-1994 have documented a significant decline of spawning biomass. In 1993 and 1994, the total observed spawning populations were less than one-third and two-thirds of pre-season prediction, with the 1994 commercial herring fisheries season totally cancelled.

The SEA Plan hypothesizes that the recruitment success of herring populations in Prince William Sound (PWS) is related to losses due to physical processes (e.g. wave action and currents) and to predation during the embryo and larval stages. This study is a continuation of research begun in FY94 by the U.S. Forest Service aimed at determining herring egg loss to avian predators. In spring 1994, avian predation on herring spawn was intensively studied on northern Montague Island. A preliminary analysis of the 1994 data is underway and initial results will be available for presentation at a Fall 1994 program review.

Understanding the factors affecting herring egg loss is necessary to accurately model herring recruitment for fisheries management. Currently Alaska Department of Fish and Game (ADFG) estimates the adult spawner biomass from total egg deposition, average fish size and sex ratio, and average fecundity at size measured. Losses to predation and physical processes before and after ADFG spawn deposition surveys are needed to accurately calculate spawning biomass and to assess the impact on recruitment to the larval stage.

Throughout incubation, egg loss can be significant. During a 2-year study in 1990 and 1991 in PWS, rates of egg loss as high as 91.2% have been measured, with an overall estimated egg loss rate of 50.4% throughout the incubation period. Predators of herring spawn include invertebrates, marine mammals, fish, and birds. Epibenthic invertebrates (crabs, snails, and starfish) and birds--primarily Glaucous-winged gulls (*Larus glaucescens*), herring gulls (*Larus argentatus*), and surf scoters (*Melanitta perspicillata*)--have been identified as the greatest sources of egg loss on spawning areas in Washington and British Columbia. Until this study began in spring 1994, only potential sources of predation were identified in PWS.

Prince William Sound has a large resident population of herring spawn avian predators including glaucous-winged gulls and surf scoters. Surf scoters are abundant in the region and the most numerous sea duck. Migrant surf scoters are numerous in April and May. Glaucous-winged gulls are also an abundant resident. Although they are present in numbers throughout the year, an influx does occur in spring, mainly between mid-april and mid-May. Historically, large numbers of glaucous-winged gulls (30-50,000) have been observed in areas with herring spawn at northern Montague Island.

Northern Montague Island is also an important spring migratory stopover for two species of shorebirds that prey on herring spawn: surfbirds (*Aphriza virgata*) and black turnstones (*Arenaria melanocephala*). In May 1992 a single day count of almost 56,000 surfbirds and 25,000 black turnstones was recorded.

Spatially and/or temporally, herring spawn deposition in PWS coincides with breeding for a large resident population of glaucous-winged gulls, and with spring stopover areas for seaducks and shorebirds. Until this study began, however, we had no information on numbers and distribution, and how predictable or variable the use of herring spawn is by resident and migrant birds. Nor has the importance of herring spawn in providing a super-abundant food resource for egg laying and migration been determined. From a fisheries management standpoint information on avian predation is important because if the avian predator population remains relatively constant or increases, the lower herring stock levels that PWS is currently experiencing could experience higher rates of predation.

NEED FOR THE PROJECT

As an injured species, Pacific herring is currently not recovering. The herring fishery is crucial to the economy and well-being of PWS communities. SEA Project No. 95320Q will continue to investigate the effects of avian predation on herring spawn survival. As part of the SEA plan, it is designed to complement ADFG's Project No. 95166, an ongoing long-term study on herring natal habitats. The goal of Project No. 95166 is to improve herring fisheries management in PWS by determining accurate and precise estimates of herring abundance. A better understanding of the loss of herring spawn to avian predators will improve estimates of egg loss used in current stock assessment models. These models are used by fishery managers to set herring harvest quotas. As part of the SEA Plan, this project will also provide further information on the regulating effect that bird predation has on recruitment into the herring population.

PROJECT DESCRIPTION

A. Objectives

The goal of this project is to assess and document the impact of avian predation on herring spawn in Prince William Sound. Results will be integrated into a model relating Sound-wide herring embryo survival to predation, habitat type, egg density, and meteorological conditions. Specific hypotheses that will be tested include:

1. Distribution, timing, and abundance of gulls, seaducks and shorebirds is positively correlated with dispersion, timing, and abundance of herring spawn.
2. Avian predation on herring spawn is a function of egg density.
3. Egg loss resulting from avian predation occurs at higher rates in years when eggs are scarce.
4. Herring spawn is a major component in the diet of bird species foraging in herring spawn areas.
5. Viable herring spawn are preferred prey compared to dead and decaying spawn.

B. Methods

The impact of avian predation on herring spawn will be documented by observing the distribution, relative abundance and behavior of birds foraging in herring spawn areas and by analyzing their diets. Herring spawn deposition density and subsequent egg loss will be documented by the concurrent ADFG Project No. 95166. The extent and distribution of herring spawn will be documented from daily aerial flights conducted as a regular part of ADFG commercial fisheries management.

The phenology, relative abundance and species composition of birds foraging in herring spawn areas will be documented using boat and aerial shoreline surveys. Avian near-shore boat surveys will be conducted at low tide along a 15-km length of shoreline containing herring spawn. Transects will include an equal amount of shoreline with and without spawn. Transect width will extend from the shoreline seaward to 120m. Data collected will include: location, number and species (or genus), shoreline type, activity, and habitat (land, water, or air).

Aerial surveys will cover nearshore areas at northern Montague Island from just south of Port Chalmers to Zaikof Bay (approximately 100km of shoreline). Surveys will be flown during low tide, at an altitude of 250-360m. A hi-band video camcorder mounted in the bulkhead of a fixed wing aircraft will be used to record numbers and distribution of gulls and scoters. VHS output will be georeferenced with the aircraft's Global Positioning System (GPS). To identify and count birds in the lab, Super-VHS images will be analyzed using image analysis software.

Foraging ecology in herring spawn areas will be determined from: scan and focal animal samples, prey availability and removal, and diet analysis. Randomly located plots including both intertidal and subtidal zones will be scanned for birds every 30 minutes over a tidal cycle. For each species, information recorded will include activity, location, and habitat (substrate and meters above or below the tideline). To document activity budgets of avian predators, a series of 10 minute focal-animal samples will be collected.

Prey availability in the intertidal zone will be determined using random transects within the boat survey area. Transect locations will be stratified between spawn and no spawn areas. Quadrats (0.01m²) will be used to sample prey items at intervals along the transect. All prey items within the plot will be quantified. Availability of prey items suspended in the water <1m below the tideline will be sampled with mesh frames.

Egg loss to avian predators will be determined using 1-m² plots containing a known egg density. Using photography, initial egg density and subsequent removal will be determined for each plot. During a 3 to 6-hr observation period, bird activity within the plot will be recorded. Bird diets will be documented by collecting esophagus and proventriculus contents from 30 glaucous-winged gulls and 30 surf scoters. Sampling effort will be proportional to the spatial distribution of each species across the intensive study area.

C. Schedule

Oct 94	Formal review of FY94 season
Nov 94	Preliminary tests of new experimental protocol
Jan 95	Logistical planning; order equipment and supplies
Feb 95	Personnel selection
Mar 95	Begin field season
Jun-Aug 95	Field season completed, data entry and data analysis, submit 96 work plan
Sep-Nov 95	Data analysis, draft report writing and internal review
Oct 95	Formal review of the FY95 season
Mar 96	Peer review of 95 report completed, final report submitted

D. Technical Support

Herring egg densities and egg loss samples from ADFG diver surveys will be processed by ADFG. Aerial surveys on extent of herring spawn will be conducted by ADFG. Results from both of these efforts will be made available to this study for further analysis. Laboratory processing of esophageal and proventricular contents as well as biometric support will be contracted. Data will be archived by project staff in accordance with standardized procedures set up for handling the SEA Plan database.

E. Location

Field research will be conducted in Prince William Sound at northern Montague Island from Port Chalmers to Zaikof Bay. High densities of herring spawn have occurred in this area nine of the last ten years. Northern Montague Island also hosts the highest numbers of migrant surfbirds and black turnstones from late April through May.

PROJECT IMPLEMENTATION

This ongoing project is being implemented by the Copper River Delta Institute, a research institute of the U.S. Forest Service. This project is part of the 95320 SEA program, a cooperative effort by Alaska Department of Fish and Game, PWS Science Center, U.S. Forest Service, University of Alaska Fairbanks, PWS Aquaculture, as well as National Biological Survey, U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration. Ongoing Copper River Delta Institute spring shorebird migration studies on the Copper River Delta will provide additional information on the phenology and habitat use of surfbirds and black turnstones.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is organized and coordinated under three of SEA's major programs: Natal Habitat, Predator-Prey, and the Database and Modeling. All aspects of field work for this study are coordinated with the Alaska Department of Fish and Game Herring Natal Habitats Study 95166. ADFG will provide herring egg densities and egg loss results from ADFG diver surveys and information on the timing and extent of spawn documented from ADFG aerial spawn surveys.

All data from this study will be archived by the project staff in accordance with standardized procedures set up for handling the SEA Plan database. The field results from the avian predation study will be integrated into the SEA plan's numerical and analytical models of the PWS ecosystem that include predation parameters and animal distributions.

FY 95 BUDGET (\$K)

Personnel	63.8
Travel	2.3
Contractual	14.3
Commodities	5.6
Equipment	2.5
Subtotal	88.5
Gen. Admin.	10.5
Total	99.0

Disease Impacts on Prince William Sound Herring Populations

Project Number:	95320S
Restoration Category:	Research (continuation of 94320S)
Proposed By:	ADFG
Cost FY 95:	\$379,900
Cost FY 96:	\$379,900
Total Cost:	Unknown
Duration:	2-3 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring and commercial fishing

INTRODUCTION

Prior to the 1993 herring spawning season, 134,000 tons of herring were forecast to arrive on the spawning grounds of Prince William Sound. Significantly less than half that amount appeared. Skin lesions, typically ulcerated, were seen on one-sixth to almost one half the fish in almost every school (except northeastern PWS). Viral hemorrhagic septicemia (VHS) was isolated from these fish but it was not determined whether this virus was the cause of the poor returns and apparent disease or simply a secondary infection in fish which were already in poor health for another unknown reason. Nevertheless, the virus which causes VHS was the only pathogen isolated from these fish. In 1994, it appears that only 20,000 tons of herring have arrived at the spawning grounds, little spawning has occurred, many ovaries are degenerate and the lesions, never a reported feature of the spawning population prior to 1993, are also abundant this year. Though human induced large mortalities of fish commonly occur in many places, natural epizootics of this magnitude are very rare. Herring are very long lived fish (to 15 years) and, in the absence of catastrophic events, dramatic population declines should not be expected.

VHS is a very poorly understood disease. It has the potential to infect many, perhaps most, species of bony fishes (fish other than sharks and rays), but its ability to produce disease varies from species to species. Salmon may be carriers, for example, while rainbow trout in European hatcheries suffer severe mortalities. Attempts to produce the disease in cod with cultures isolated from other cod have met with mixed success.

In 1994, the Trustee Council sponsored investigation of herring disease in Prince William Sound. VHS was again isolated from spawning Prince William Sound herring, but it remains unknown whether this pathogen is a significant cause of the decline in the size of the PWS herring population. Diseased animals have been observed during spawning, but it is unknown whether this epizootic is in progress prior to spawning or continues after spawning. Though large interannual mortalities are apparent, it is unknown whether these are concentrated during any particular part of the year and what other factors besides VHS may be associated with them.

NEED FOR THE PROJECT

Prince William Sound Pacific herring (*Clupea pallasii*) support five commercial fisheries in PWS with an annual average ex-vessel value of \$8.3 million. In addition, several thousand pounds of herring and herring spawn on kelp are harvested annually for subsistence purposes and form an important part of the local native culture of Chenega and Tatitlek. Pacific herring provide important forage for many species including some species severely injured by the *Exxon Valdez* oil spill. Predator species include humpbacked whales, seals, sea lions, gulls, sea ducks, shore birds, halibut, salmon, rockfish and other fish. Significant declines in marine birds and mammals which eat forage fish have been reported from Prince William Sound. Decline in the prey base, of which herring constitute a major portion, has been implicated in decline in bird and mammal numbers. Thus a major reduction in herring numbers in Prince William Sound has the potential for significant impacts throughout the ecosystem. It is incumbent upon the Trustee Council to investigate circumstances which could seriously limit the recovery of species injured by the *Exxon Valdez* oil spill. Collapse of the herring population has that potential.

PROJECT DESIGN

The design for this project is yet to be determined because requests for proposals are being solicited through the State of Alaska Multi-Step procurement process. Nevertheless, some general statements may be made at this time.

A. Objectives

Determine the epizootiology of disease-associated decline in the size of the Prince William Sound Pacific herring population including microbial, anthropogenic and environmental causes.

B. Methods

To be determined by successful bidder.

C. Schedule

To be determined by successful bidder.

D. Technical Support

To be determined by successful bidder.

E. Location

Prince William Sound

PROJECT IMPLEMENTATION

This project is to be implemented through the State of Alaska Multi-Step Procurement Process. Some logistics and pathogen diagnostic testing may be provided by the Alaska Department of Fish and Game if this is determined to be necessary for the successful completion of this project.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This subproject was added to 94320 (Prince William Sound System Investigations) in 1994 and is expected to be part of this project in 1995. This subproject is closely allied with many of the other subprojects of 94320, with Project 94166 (Herring Spawn Deposition and Reproductive Impairment), and with Project 94163 (Forage Fish Influence on Injured Species). If VHS is a primary pathogen, a catastrophic decline in herring abundance will occur despite other environmental parameters which might be favorable and which are being investigated by other 94320 subprojects. Conversely, VHS may also be a sign of environmental stress and merely a secondary invader. In that case it would be much less responsible for the decline in the herring population than possibly adverse environmental conditions. Demonstrating the cause of the population decline may ultimately require information from these other subprojects. The health of the herring population in Prince William Sound will impact those animals with which it competes and those resources which prey upon it. Integrated information from the herring health subproject and the spawn deposition and reproductive impairment project may be able to predict the course of recovery for Prince William Sound Herring.

FY 95 BUDGET (\$K)

Personnel	9.0
Travel	0.0
Contractual	350.0
Commodities	0.0
Equipment	0.0
Subtotal	359.0
Gen. Admin.	20.9
Total	379.9

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Juvenile Herring Growth and Habitat Partitioning

Project Number:	95320T
Restoration Category:	Research (new)
Proposed By:	ADFG and University of Alaska Fairbanks
Lead Agency:	ADFG
Cost FY 95:	\$340,300
Cost FY 96:	\$584,500
Total Cost:	Unknown
Duration:	3-5 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring and commercial fishing

INTRODUCTION

Prior to the *Exxon Valdez* oil spill, there had been no baseline studies conducted to document distribution or abundance of larval or juvenile forage fishes including herring in Prince William Sound (PWS). Because little was known about the early life history stages of herring in PWS, estimates of oil exposure and documented effects on specific processes such as growth and mortality was difficult. We documented injury to the embryos and newly hatched larvae in 1989 and the precipitous decline in the spawning population in 1993. However, the gap in our understanding of what happened to the exposed larval and juvenile herring between 1989 and 1993 resulted in an inability to link cause and effects. We could not entirely separate the effects of oil exposure from those due to changes in oceanographic conditions, zooplankton abundance or density dependent predation. As we now take an ecosystem approach to answering questions about herring, we can fill in this gap in our understanding of the early life history stages. Through Prince William Sound Systems Investigation, Sound Ecosystem Assessment (SEA), we will address predator/prey relationships, physical processes affecting natal habitat, environmental factors controlling juvenile growth, mortality, and ultimate recruitment as adults, the relationship between transport of larvae and surface and subsurface currents in the sound, and location and condition of juvenile and adult herring in the winter. The proposed study will address the broader issue of what is causing the demise of herring in PWS by investigating dynamics of juvenile herring.

An ecosystem approach is needed now because lack of such an approach immediately following the oil spill caused interpretation of larval abnormality indices and the cause of the herring disease to be questioned. In 1993 and 1994 the adult spawning biomass was greatly reduced over previous years and showed a high incidence of skin lesions and occurrence of VHS virus. It is well known that exposure to oil can weaken the immune system in fish. This population is composed largely of fish that were one year old during the spill, of which we knew very little. However, because historic information indicated that the area covered by the oil trajectory overlapped the distribution of juvenile herring to a large degree, we suggested that the potential for exposure through ingestion of oiled particles and prey was great. Although the 1989 year class contributes under 5% of the affected population, the overlap between the oil trajectory and the drifting larvae was over 80% in 1989 resulting in a great exposure risk and potential for succumbing to disease. Abnormalities in free-swimming larvae were documented, but without a baseline index of occurrence we could not estimate the oil induced perturbation. Whether or not this year class, once infected, could have exposed the rest of the adult population when it fully recruited as four-year-olds in 1993 is speculative.

Many researchers now feel that understanding the early life history stages is crucial to understanding the variability and cyclic behavior of herring recruitment. The factors affecting the abundance of recruits are believed to include changes in predator abundance, zooplankton biomass, and oceanic conditions. Recent studies have also pointed to the importance of available habitat providing spatial refuge from predators and a nearby food supply. In addition, predator abundance and food availability affect foraging behavior (evidence of optimal foraging) and density dependent mortality of juveniles. Survival of larvae is probably less deterministic of ultimate recruitment than survival of juveniles; however, some years advective processes probably do impact herring recruitment. Because larval and juvenile stages lack density dependent growth mechanisms, density dependent predation is probably more important. Through the findings of this study and related SEA programs, we hope to describe the relative importance of zooplankton or food abundance, oceanic conditions, habitat requirements, and density dependent predation in determining the large fluctuations in abundance observed. In future years, we will continue to document those variations induced by the *Exxon Valdez* oil spill by defining baseline levels of morphologic and cytogenetic abnormalities (which were believed to be elevated in 1989) occurring in PWS larvae. In future years, the development of the ocean state model will enable us to describe advective processes of larval herring, its relative importance in determining recruitment, and its importance in determining distribution of juvenile herring inside and outside of the Sound.

NEED FOR THE PROJECT

The target species of this study is Pacific herring, one of the species listed by the EVOS Trustee Council as damaged and not recovering. This species experienced poor recruitment in 1993, when the 1989 year class would have been expected to enter into the fishery a disease (VHS) plagued the returning adult population. The resulting population crash which continued into 1994 resulted in reduction of the herring fishery in 1993, closures of all fisheries in 1994, exacerbating the already depressed economic state of the region. In addition, the herring

population decline has countless effects on the ecosystem including oil spill injured apex predators. Understanding and monitoring the recovery of this important species will be crucial to understanding the restoration of the species that feed upon them.

PROJECT DESIGN

This three to five year study will address several core hypotheses of the SEA including: 1) oceanographic and meteorological effects on plankton dynamics and fish distribution, 2) predator/prey relationships, 3) herring condition and overwinter survival.

A. Objectives

The overall objective of this multi-year project is to understand interannual variability in successful year classes of herring in PWS. This can be accomplished by examining the fish in the context of their total environment including their general distribution, the meteorology and oceanography driving the system, and the biology of the lower trophic levels which act as food for small herring. During the first year, we will collect basic biological and baseline information needed to refine study design. During the second year and beyond, we will examine finer scale processes and habitat characteristics affecting juvenile herring growth and survival. The juvenile fish aspect of the ecosystem study will achieve the following objectives this year:

1. To determine the general distribution and habitat characteristics of juvenile herring in the nearshore and offshore waters of western and southwestern portions of PWS.
2. To identify bays that are utilized by juvenile and adult herring during summer rearing.
3. To subsample these bays, and determine the relative distributions of juvenile herring and co-existing species in both bays and passes in PWS.
4. To determine the diet composition and relative food abundance compared to the relative juvenile herring abundance sampled in both bays and passes.
5. To compare age composition and growth of herring (using length frequency and size-at-age analyses) between areas and between bays and passes.
6. To determine levels of predation and relationships between juvenile herring predation rates, juvenile herring abundance, and macro-zooplankton abundance observed in bays and passes.
7. To determine the temporal and spatial differences in oceanic conditions in rearing areas in both bays and passes.
8. To monitor the age composition, growth, condition factor, food availability, and predation rates on a subsample of overwintering juvenile herring populations in PWS.

Although larval collections of herring will be made in FY95 by the zooplankton project within SEA, sample processing, data analysis, and interpretation will be completed in FY96 pending funding.

B. Methods

We will be collecting information on juvenile herring from two main locations: 1) four to six passes, bay mouths and offshore waters of western and southwestern PWS and 2) inside 4-6 bays typically utilized by juvenile herring during the spring and summer stratified by eastern, western and southwestern PWS. In the passes, juveniles and their predators will be collected by trawl (offshore) and seines (nearshore) by the Juvenile Salmon and Herring Integration project of SEA. Physical oceanography and zooplankton data are collected simultaneously by the Zooplankton in the Ecosystem and oceanography components of SEA that share the research platform. General distribution in the passes will be determined acoustically by the Nearshore Fish/Acoustics project of SEA. Signal processing and analysis of acoustic data collected in bays will be contracted. In the passes, sites will be visited every two weeks. In the bays, juveniles will be sampled using bait seines, shared with the salmon and forage fish projects, and physical data, zooplankton, and hydroacoustics will be collected from a smaller companion vessel. Sampling will be more intensive in bays with collection of at least three sets of continuous data through tidal cycles stratified by month and location. These data, together with information on the structure of the area (e.g. depth, distance offshore) will be used to classify the nursery habitat utilized by juvenile herring.

Objectives will be met through analyzing data collected by the various platforms. The Juvenile Salmon and Herring Integration study (95320E) will provide data to meet objectives 1 in full and 3, 4, 5, 6, and 7 in part. Data collected and processed by the integration study to be analyzed by this study include juvenile herring distribution, relative densities, diet composition (stomach contents already processed), co-existing species, length frequency, weight and age to satisfy objectives 1-7. The majority of the bay-caught juvenile herring sample processing and data analysis will be accomplished through reciprocal service agreements (RSA) with the University of Alaska, Fairbanks. The acoustics project of SEA will provide some of the broad-scale distribution and relative abundance information needed to complete objective 1. The remainder of the data needed to satisfy objective 1 will come from the Physical Oceanography project of SEA as well as physical data collected by this study. This study will in turn provide samples to the bioenergetics of PWS herring and related species study which will provide information of somatic energy cycles, condition factors, sexual maturity and ovarian energy indices relative to the other indices of juvenile herring. Pending support from and coordination with the community transfer coordinator for the Trustee Council, we will work with the high schools in the region to develop a volunteer data collection scheme to sample winter aggregations of juvenile herring occurring near the municipalities.

Aggregations of juvenile herring in bays throughout PWS will be identified by ADFG overflights conducted by the regularly conducted salmon escapement surveys (general funds) and by our project. Aerial surveys will be conducted weekly over a six-week period. A high resolution 8 mm video camera, that is directly linked to a GPS and downloadable to GIS, may be used during aerial surveys to track aggregations. There will be a separate contract for GIS data processing. Potential sample locations, derived from the historic literature, include bays in eastern PWS (Port Fidalgo including Fish Bay and Irish Cove, Port Gravina including Beartrap Bay, Jack Bay off of Valdez Arm), western PWS (Pt. Chalmers, MacLeod Harbor, Hanning Bay on Montague Island; Snug Harbor and Herring Bay on Knight Island; Naked Island; Port San Juan on Evans Island; and McClure, Main, Eshamy, and Whale Bays) and the southwestern exit (Puget Bay).

A variety of statistical methods and fisheries models will be used to analyze the data. As in the integration study, multiple regression analysis will be used to examine the relationship between feeding rates (dependent variable), predator feeding rates (dependent), and macro-zooplankton abundance (independent variable) to assess density-dependent mortality due to predation in order to meet objective 6. Growth rates between sites and among years will be compared using an ANOVA. Because aging of daily growth rings in otoliths of juvenile herring is time consuming it will only be employed on a small subsample of herring collected using methods outlined by McGurk. For a larger percentage of herring juveniles, we will use a time sequence of length frequency histograms to reveal growth of the fish over the study period. Stomach contents analysis will be used to estimate the diet composition of juvenile herring, with prey identified to the lowest taxonomic level. An ANOVA will be conducted to test differences temporally and spatially. Using the zooplankton abundance data and growth rate analysis, a simple bioenergetics model will be applied to evaluate whether the growth of juvenile herring was likely limited by low prey density. Relative fish abundance data (CPUE) will be related to several parameters of physical conditions including habitat characteristics using linear discriminant function analysis. A stepwise multiple regression is used to further refine the relative importance of the factors.

C. Schedules

October 1994 - January 1995

Finalize detailed study plan, coordinate with all companion projects and investigators based on results of 1994 sampling.

January - March 1995

Stage for FY95 field season.

Mid-May - July 1995

Field work in Prince William Sound, begin sorting and identification of stomach contents analysis and other lab work.

August - September 1995

Preliminary analysis of data.

D. Technical Support

This project requires strong supporting projects from other SEA projects including Physical Oceanography (PWSSC), Nearshore Fish/Acoustics (PWSSC), Pink Salmon and Herring Integration (ADFG/UAF), and Bioenergetics of Herring and Related Species (UAF). The bulk of the data processing, analysis and report preparation will be conducted by staff at UAF.

E. Location

We will concentrate on the PWS herring population. Although there is evidence that adult herring utilize offshore feeding grounds on the continental shelf adjacent to their spring spawning area, the data available suggest that juveniles remain in nearshore areas to feed year around. Therefore, we will concentrate in the nearshore bays and passes within and immediately bordering Prince William Sound.

PROJECT IMPLEMENTATION

Alaska Department of Fish and Game will take the lead with the majority of the data processing and analysis conducted through RSA with the University of Alaska, Fairbanks with Brenda L. Norcross as the Co-Principal Investigator supervising all work. Dr. Norcross conducted a larval fish study in PWS in 1989, is a fisheries oceanographer, and is the logical choice for this position. Involving a new individual would involve additional costs in bringing them up to speed.

COORDINATION OF INTEGRATED RESEARCH EFFORT

The proposed study is a new part of the integrated Prince William Sound Ecosystem Assessment (SEA) which was initiated in 1994. This project is designed as an interdisciplinary study which focuses on transport of herring larvae but is dependent upon results of the concurrent Salmon and Herring Integration Project, Physical Oceanography and Nearshore Fish/Acoustic projects through shared data and resources and integrated sampling plans. This study will use results generated by Zooplankton in the Ecosystem, Phytoplankton and Nutrients, Bio-energetics of Herring in PWS, and the VHS study which was initiated in April 1994 on an emergency basis. It will also be coordinated and conduct data-sharing with FY95 studies on forage fish, pelagic seabirds, and marine mammals. The information gained from this proposed study will contribute to the PWS herring recruitment model that is part of the Herring Natal Habitat study.

FY 95 BUDGET (\$K)

Personnel	58.1
Travel	2.0
Contractual	248.8
Commodities	6.3
Equipment	0.0
Subtotal	317.9
Gen. Admin.	25.1
Total	340.3

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Somatic and Spawning Energetics of Herring and Pollock

Project Number:	95320U
Restoration Category:	Research (new)
Proposed By:	University of Alaska Fairbanks
Lead Agency:	ADFG
Cost FY 95:	\$99,400
Cost FY 96:	Unknown
Total Cost:	Unknown
Duration:	3 years
Geographic Area:	Spill area
Injured Resource/Service:	Pacific herring

INTRODUCTION

This project will focus on the seasonal somatic energy cycles of two important forage species in the EVOS region: the Pacific herring and the walleye pollock. It will also explore over-winter survival of juvenile herring and herring reproductive biology. Historically, herring and pollock have been among the most abundant pelagic forage fishes in southcentral Alaska. After the *Exxon Valdez* oil spill the herring population of Prince William Sound has been exhibiting reduced abundance, disease, and spawning anomalies that may be related to pollution. This research effort will focus on energetics and spawning biology of herring from Prince William Sound.

Based on larval surveys, pollock are known to be abundant in the EVOS region. Little is known about *in situ* pollock energetics but, like herring, they are heavily preyed upon by commercially important fish species, sea birds and harbor seals. This project will provide the energetic information necessary to quantify trophic interactions involving pollock.

Forage fishes are key components of the pelagic food web. They are both predators and prey and their energy cycles reflect the overall production process. This energetic work will provide the basic information needed to quantify trophic interactions for two of the most common forage species in the EVOS region. A long term monitoring program of energy flow in both herring (*Clupea harengus pallasii*) and pollock (*Theragra chalcogramma*) may also provide some insight into how these two key forage species interact. The study of herring reproductive biology

will be useful in managing the roe fishery.

Typically high latitude fishes store energy during summer and fall feeding and throughout the winter reallocate energy to reproduction. Thus, seasonal tissue samples must be taken to account for the temporal variation in energy content.

NEED FOR THE PROJECT

The invitation to submit restoration projects identifies food web studies as having a high priority. Basic to all food web studies are energy flow models which are used to quantify how species interact, energy transfer rates, food web changes, energy balances and reproductive success in the injured species. The primary information needed for these interaction models are population estimates and measurements of energy content of the food web species. This proposed study would provide seasonal somatic energy for two key forage species, herring and pollock, which are known to be important in the EVOS area food web.

There are no previous reports on energy allocation, or over-winter mortality, in Alaskan herring. Historical measurements of length, weight, age and roe yields are available in a variety of ADFG, and other agency reports. Work by the authors on Pacific cod demonstrated that energy storage in liver varied by 116% in the two years that it was measured. In cod 46% of the energy channeled to gonads comes from liver and soma, thus reproductive output is directly related to these energy pools. It is reasonable to assume that similar variations, or perhaps even larger fluctuations, exist in energy cycles of herring, but only quantitative sampling will validate this theory.

A considerable amount of laboratory work on growth related bioenergetics of juvenile pollock have been accomplished. For juveniles somatic energy content has been related to condition factor. However, there is no information on intraannual and interannual variation in somatic energy content.

PROJECT DESIGN

A. Objectives

1. Describe the seasonal somatic energy cycle of juvenile and adult herring and juvenile pollock.
2. Describe the spawning energetics and reproductive biology of herring.

3. Examine winter mortality of juvenile herring and critical condition factor.

This project will measure ovulation and reabsorption rates for EVOS Pacific herring and ovarian energy indices relative to condition factor index, disease, somatic energy, and liver energy indices. The seasonal energy content of juveniles will be measured and critical condition factor determined in the laboratory so that estimates of *in situ* winter mortality can be made. For walleye pollock seasonal somatic energy cycles will be described. Collections will include all age classes of pollock commonly preyed upon by bird and mammal species injured by the oil spill.

B. Methods

The methods applied to both pollock and herring will be similar to those used by the investigator in previous bioenergetic studies. Adult herring will be collected every other month and just prior to and after spawning by ADFG and frozen. In the laboratory they will be divided into groups based on sex, length (or age) and condition factor where $CF = g \text{ wet wt} \times 100 / (\text{cm fork length})^3$ as well as disease status. There will be a minimum of 100 fish in each sample. Wet weight will be measured to the nearest tenth of a gram. Fish will be dissected and gonad and liver weight measured. Small subsamples of axial muscle, gonad and liver will be removed for energy measurement. Each fish will be individually tagged and freeze dried. After freeze drying they will be placed in a convection oven at 60°C until they reach a constant weight. Individual wet and dry weight values will be used to calculate the moisture content. Dried individuals will be ground in a mill and measurements of ash and caloric content made. The percentage of ash will be determined by weighing a subsample, placing it in a crucible with a loose fitting top, and heating gradually over 3 h to 600°C and maintaining the temperature for 1 h. The muffle furnace will be allowed to cool to room temperature before opening. Sample energy content will be determined by bomb calorimetry. For juvenile herring and pollock from every sample, whole body energy will be measured but individual organs will not be examined.

Fecundity measurements will be made for 100 herring from each of the study areas based on weight of the ovaries, taking a sample equal to 10% of the ovary weight from each ovary and counting the number of eggs to measure the weight of one egg. Ovary weight times the weight of one egg will provide the estimate of total fecundity. Samples will be taken prior to any observed spawning and after spawning. Estimates of eggs not spawned will be obtained from the post spawning samples.

Herring samples will be taken from two different geographical areas in Prince William Sound. Specific sampling sites will be coordinated with bird and mammal projects. This type of information will provide insight into the extent of geographical variations in somatic energy storage. Critical condition factor for juvenile herring will be measured in the laboratory. The same basic methods outlined for herring will be used for measuring pollock somatic energy content. Samples will be taken from four different geographical areas. Specimens will be captured using small trawls and additional samples will be solicited from researchers who obtain specimens from birds. Specific sampling sites will be coordinated with bird and mammal projects.

Proximate analysis will be carried out on tissue samples using the facilities of a commercial or university service laboratory. Live juvenile herring will be held in the laboratory and measures of conversion efficiency relative to condition factor of fish will be made using modified methods of Paul *et al.*, in press and Harris *et al.*, 1986. Fish will be captured periodically throughout the over-winter period to obtain fish with different condition factors. Herring will be fed commercial fish pellets to determine at what condition factor they have reached the point of no return.

C. Schedule

Samples of both species will be taken over a three year period. A study of this duration is necessary to provide some estimate of what normal values would be for these previously unmeasured parameters. A minimum of three years is needed to observe interannual variations in energy cycles and provide enough data to model condition factor and liver energy storage relative to prespawning ovarian energy.

The milestone chart below outlines the proposed schedule events for the first year of study:

Oct 1 94-Aug 31 95	Bimonthly field sampling for pollock and herring for somatic energy measures
Oct 1 94-Aug 31 95	Sample processing for pollock and herring
June 1 95	Progress report
June 15 95	Renewal proposal
Sept 30 95	Annual report

Years two and three would have similar schedules with the addition of laboratory studies of critical condition factors for juvenile herring. The final report would be completed by January 1, 1998. Modifications in due dates dictated by revisions in the proposal process will be incorporated as required by the funding agency.

D. Technical Support

It is assumed that all collections of herring will be done by the Alaska Department of Fish and Game and that pollock will be collected by the forage fish project so no funding for vessel time is requested. If it proves unfeasible to get samples from the forage fish project then a supplemental request for vessel time will be submitted. All laboratory facilities and equipment needed for this project are available at the Seward Marine Center laboratory.

The data will be fitted to linear, logarithmic, power and exponential curves and the r^2 goodness of fit value used to determine which curve is the best model to describe the interrelationships between size and energy content, season and energy content, condition factor and whole body energy, liver energy and ovarian energy content, or length fecundity relations using SIGMASTAT and SIGMAPLOT software and existing computers. ASCII files will be used to archive the data.

E. Location

Herring samples will be taken in Prince William Sound in conjunction with ADFG sampling. Pollock will be collected around EVOS rookeries and seal feeding areas in conjunction with the forage fish project.

PROJECT IMPLEMENTATION

Virtually all the bioenergetics work on Alaskan marine fish and invertebrates completed to date has been done by the author of this proposal (Dr. A. J. Paul) and his colleagues and all this work has been done at the Seward laboratory. This combination of experience and facility makes IMS Seward a logical place to do fish and invertebrate energetics.

FY 95 BUDGET (\$K)

Personnel	3.0
Travel	0.0
Contractual	92.6
Commodities	0.0
Equipment	0.0
Subtotal	95.6
Gen. Admin.	3.8
Total	99.4

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Sound Ecosystem Assessment (SEA)/Prince William Sound System Investigation--Variation in Local Predation Rates on Hatchery-released Fry

Project Number:	95320Y
Restoration Category:	Research (new)
Proposed By:	Prince William Sound Science Center
Lead Trustee Agency:	ADFG
Cost FY 95:	\$161,200
Cost FY 96:	\$94,800
Total Cost:	Unknown
Duration:	2 or more years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink salmon

INTRODUCTION

The Sound Ecosystem Assessment (SEA) program relies upon testing a set of core hypotheses to achieve its goals of understanding marine production in Prince William Sound. The 'predator-prey relationship' hypothesis of SEA suggests that predation on early life stages of pink salmon and herring is an important modulator of survival, and that the intensity of this predation depends on the availability of alternative prey such as macrozooplankton. Initial carbon budget models suggest that the primary predators on 0-age class fish may be pollock, but there are not sufficient data to state this with certainty. The Pink Salmon and Herring Predation project (94320E) is designed to evaluate the significance of fish predation on 0-age class fishes, focusing on the pink salmon out-migration pathway from fry emergence into the marine environment until the juveniles leave the Sound.

During May 1994 at the Esther Island hatchery (WNH, Lake Bay), SEA researchers noted hundreds of birds, including primarily terns, gulls, and mergansers, feeding near hatchery release sites. The acoustic and net sampling at the same time did not reveal correspondingly high predation by fishes. In contrast, however, the same observations at Evans Island hatchery (AFK) found evidence of juvenile pollock aggregating around fry schools, but did not note substantial bird aggregations. These field observations suggest that in some cases, predation on young fish by birds may be as important as predation by larger fishes. This is a reasonable supposition in light of data from other areas, documenting the importance of avian predation on

schools of small fish at both local and regional scales.

This proposal is for funds to record the size, composition, behavior and duration of foraging aggregations (including mammals, if appropriate) at salmon hatchery release sites. These data will be interpreted in conjunction with results of other projects (that will provide data on prey abundance and distribution) to evaluate the intensity and spatial variation in tetrapod (i.e. bird and mammal) predation on hatchery fry schools, and to test a series of hypotheses explaining that variation. Examination of predation on these hatchery schools of small fish will also provide insight into bird and mammal foraging aggregations on other schooling fish, such as herring or forage fish.

NEED FOR THE PROJECT

Pink salmon are an important resource in Prince William Sound that is not recovering from damage by the *Exxon Valdez* oil spill. Hatchery production of pink salmon fry is an important and economically valuable tool that has been successfully applied to enhance pink salmon populations and fisheries in the Sound. However, variation in the success of pink salmon releases are not currently understood.

Results of SEA and preceding investigations suggest that predation is an important moderator of pink salmon survival, and that bird predation on hatchery-released fry may be at least as important as predation by larger fish. This study is needed to evaluate the localized intensity of predation rates on hatchery-released fry, and to understand the mechanisms generating spatial, seasonal, and year-to-year variation in predation intensity. Results of this study will be useful in designing optimal fry-release strategies to minimize losses to predation. Results may also be generally applicable to understanding the efficiencies of birds and mammals foraging on small, schooling fish, and thus to testing the food limitation hypothesis as an explanation of declines in pelagically foraging bird and mammals.

This project is a component of SEA essential to evaluating the predator-prey relationships hypothesis that predation regulates pink salmon survival and is moderated by the availability of alternative prey. Techniques, equipment, and support structure (e.g. a volunteer program) used in this project may also be applicable to the herring overwintering program under SEA, as understanding localized predation on juvenile herring is one goal of that program. However, no data collection on herring are proposed under this budget.

PROJECT DESIGN

A. Objectives

General

The primary goal of this proposal is to estimate the relative intensity of localized predation on hatchery-released salmon fry for one to two weeks after release, to describe variation in local predation intensity, and to provide tests of hypotheses accounting for this variation. The short period following release is when predation on fry is likely most intense, because 1) fry have not dispersed yet and hence are a locally dense food source, 2) fry are still small, and 3) fry may be unusually vulnerable because they are naive. It is also the period when fry can be most reliably located by researchers, because their location and abundance is known at the time of release.

Field observations and other studies suggest that predation by birds may be substantial relative to predation by fish, and that predation intensity is locally variable. This project proposes four hypotheses to account for spatial, seasonal, and year-to-year variation in local predation intensity on fry:

1. Variation in local predation intensity on fry are determined by the distribution and abundance of alternative prey, including macrozooplankton and other small fish (Prey-switching hypothesis).
2. Variation in local predation intensity on fry is determined by the energetic cost of foraging. Assuming that distance to forager breeding colonies is one measures of energetic costs, since birds must return from foraging trips to this central location. (Energetic costs hypothesis).
3. Variation in local predation intensity on fry is determined by prey vulnerability. Hatchery fry are naive and hence unusually vulnerable (Vulnerable prey hypothesis).
4. Variation in local predation intensity on fry is determined by risk to foragers of feeding. For example, high bald eagle activity in some areas may make foraging there more risky than feeding elsewhere (Risk hypothesis).

These hypotheses address the four variables known to influence feeding rates of predators: missed-opportunity-costs (of foraging elsewhere), energetic costs, success rate, and the risk of foraging.

For 1995

Sampling will be conducted near hatchery release sites in the one to two weeks immediately following release. Sampling will therefore occur between mid-April and mid-May of 1995. Five to ten days of additional sampling will be done in June if a late-release is conducted.

Objectives for this project are:

1. Record size and composition of foraging aggregations near hatchery-release sites following releases.
2. Sample behavior at foraging aggregations to measure dive and capture rate for foragers that bring prey to the surface before consuming them (e.g. gulls and terns).
3. Organize volunteer observers at each hatchery release site in PWS to record the qualitative abundance and composition of foraging aggregations near hatcheries during release and post-release periods. This will provide wider geographic coverage at minimal cost to estimate the extent of variation in foraging aggregations.
4. Opportunistically repeat size/composition and behavior sampling of foraging aggregations located on schools of wild fry. This data will form part of the test of the Vulnerable prey hypothesis
5. Using data from this proposal and from salmon growth, salmon predation, and nearshore acoustic projects, estimate the extent of local predation on hatchery-released fry in the 7-14 days following release.

B. Methods

Data will be collected at two hatcheries (Esther Island and Evans Island), on an alternating schedule designed to include the 7 days following as many releases at each hatchery as possible.

1. Size and composition of foraging aggregations: Foraging aggregations will be observed from a small boat and from shore. Sampling will start at the time of release or slightly before, as foragers are not expected to aggregate at release sites until prey becomes available. All foragers present (including potential predators on foraging birds) will be counted and identified to species if possible, or to species group, and foraging behaviors noted. Aggregations will also be photographed for later counting. Repeated counts throughout the release period will be used to measure variation in the aggregations over time. Data from other SEA and hatchery projects will be used to track the fry schools for up to 14 days post-release.
2. Behavior: Focal-animal sampling will be conducted on-site if possible, and from video tapes otherwise to estimate dive rates for each prominent species (or species-group) of forager and to estimate capture rates for each species that brings food to the surface before consumption (e.g. gulls and terns). Response to and interactions with potential predators (e.g. eagles) will be recorded to estimate impact of predation risk on foraging.

3. Volunteer organization: Each hatchery in PWS will be contacted to recruit volunteers to keep notes and the size and composition of bird aggregations near release sites. Data forms, instructions, binoculars and bird identification guides will be loaned to volunteers as necessary. Volunteers will be asked to daily record foraging aggregations near the hatchery.
4. Opportunistic sampling of aggregations on wild fry: SEA sampling boats are attempting to locate and track wild and hatchery schools of fry. If wild fry schools are located during the field sampling period and are logistically accessible, the same sampling techniques will be used on wild fry schools to estimate predation intensity on wild schools.
5. Analysis: Estimated local predation rates will be calculated from flock size, and dive success rates recorded from focal-animal samples. Variation in predation intensity will be obtained from comparison of the two focal sites, and from the volunteer data set. Hypotheses will be re-examined and evaluated in light of this data.

C. Schedule

Jan - 14 Apr	Organize logistics, purchase equipment and organize volunteers
17 Apr - 19 May	Field work at hatcheries
22 May - 30 Sep	Analysis and report writing

D. Technical Support

This project will require normal hatchery operations to provide fry releases, and is provided logistical support through hatchery operations (equipment and personnel transport, volunteers, lodging). This project benefits from the availability of acoustic and net sampling data from SEA programs including Pink salmon growth and mortality, Salmon predation, and Nearshore fish and acoustics.

E. Location

This research will be conducted in Prince William Sound. Field work will be located at or near hatchery release sites and analysis will occur at the PWS Science Center.

PROJECT IMPLEMENTATION

This research is proposed by and should be conducted by the Prince William Sound Science Center. This work is an integral part of the SEA program and relies on close interaction and access to SEA researchers and data. It is also designed to complement other proposed research involving Science Center collaboration, including components of the SEA Herring program, SEA Predator-prey program, the Science Center proposal to conduct a Forage Fish assessment, and a proposal for sampling foraging efficiencies at food patches.

COORDINATION OF INTEGRATED RESEARCH EFFORT

As part of the SEA program, this project is coordinated with the SEA integrated research effort. SEA coordinating efforts include the SEA Planning and Communication project, SEA Information Systems Modeling. The proposed research contributes to SEA programs on predator-prey relationships, herring overwintering, and modeling. This project is also designed with input from the Pelagic Predators and Nearshore work groups and complements research proposed within those groups. The PI of the proposed work has been and will continue to be an active participant in SEA program and EVOS Trustee meetings to integrate research.

FY 95 BUDGET (\$K)

Personnel	6.0
Travel	0.0
Contractual	144.2
Commodities	0.0
Equipment	0.0
Subtotal	150.2
Gen. Admin.	11.0
Total	161.2

***Exxon Valdez* Restoration Reserve**

Project Number:	95424
Restoration Category:	Restoration Reserve (continuation of 94424)
Lead Trustee Agency:	All Trustee agencies
Cost FY 95:	\$12,000,000
Cost FY 96:	\$12,000,000
Total Cost:	~~\$108,000,000~~
Duration:	Annual through 2002
Geographic Area:	Oil spill area
Injured Resource/Service:	Multiple resources

INTRODUCTION

Complete recovery from the *Exxon Valdez* oil spill will not occur for decades. Scientists have identified a clear need to establish the capability to act in the years after 2001. For example, some salmon return in cycles of four to six years, and other resources have lives that are much longer. To be effective, activities may have to span more than one generation. Sometimes research is necessary to understand why a resource is not recovering. In many cases, research must precede effective restoration or improved management decisions that will protect a resource or service. For these reasons, some restoration activities may continue for a long time.

Annual payments to the Restoration Fund end September 2001. The *Exxon Valdez* Restoration Reserve provides a location to hold funds for restoration activities after the last annual payment. Allocation of the Reserve to specific activities will be made by the Trustee Council at a later date.

The \$12 million of this project would be the second payment toward the *Exxon Valdez* Restoration Reserve. One payment of \$12 million was authorized by the Trustee Council on January 31, 1993 as part of the 1994 Work Plan. Additional annual deposits of \$12 million payments made each of the remaining seven years would provide a reserve of \$108 million plus interest. This amount is expected to be appropriate to carry out long-term restoration activities needed after Exxon payments end.

The *Exxon Valdez* Restoration Reserve could potentially benefit any resource or service injured by the oil spill.

NEED FOR THE PROJECT

The \$12 million of this project and future payments to the *Exxon Valdez* Restoration Reserve will fund restoration activities after the annual payments end. Interest earned on the Reserve's principal will remain with the Reserve until needed.

PROJECT DESIGN

A. Objectives

The sole objective for the Reserve is to assure the availability of funds to allow the Trustees to continue restoration activities that are necessary for recovery of resources and services injured by the oil spill after the last annual payment to the Restoration Fund.

B. Methods

Not Applicable.

C. Schedule

Not applicable.

D. Technical Support

Not applicable.

E. Location

Oil spill area.

PROJECT IMPLEMENTATION

The Reserve will be held by the Court Registry. Expenditures from the Reserve will be made only at the direction of the Trustee Council. Any spending from the Reserve must be consistent with the Consent Decrees that established the Restoration Funds and with the Memorandum of Understanding between the state and federal governments.

FY 95 BUDGET

Approximately \$12 million each year, FY 1994 through FY 2002, for a total of \$108 million (plus interest).

Harlequin Duck Recovery Monitoring

Project Number:	95427
Restoration Category:	Monitoring (continuation of 94427)
Proposed By:	ADFG
Cooperating Agencies:	DOI, NOAA
Cost FY 95:	\$226,900 (includes \$17,300 for data analysis and report writing of FY 94 work)
Cost FY 96:	\$294,700
Total Cost:	Unknown
Duration:	6 years
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harlequin duck

INTRODUCTION

Oil spill studies of harlequin ducks in western Prince William Sound (PWS) 1989-93 indicate an initial mortality up to 1,000 birds (spill-wide), consistently low numbers of birds during the breeding season, a lack of breeding activity on suitable streams 1991-92, negligible production of broods through 1993, and an apparent decline in post-breeding molting birds in the region. Two main hypotheses have been followed to explain these findings: (1) ingested oil is continuing to cause mortality and/or sublethal impairment of reproduction; and/or (2) initial mortality caused significant losses to the local western PWS breeding component and subsequent low production. To date, oil has been found in a few harlequins collected during 1989-90 and 1993, and they continue to feed in oiled areas year around. However, no conclusive evidence has been found of histological or physiological effects from oil.

The most important conditions for successful restoration are: (1) establishment of a monitoring program for spring and summer population structure and detection of reproductive effort, and (2) mitigation of physiological impairment that may result from ingesting contaminated foods. Otherwise, natural improvements in productivity or enhancement efforts will be undocumented or ineffectual.

Because of the consequences of a continued harlequin duck reproductive failure, it is particularly important to understand what factors are responsible for limiting reproduction. Given the lack of recovery and the suspected high degree of site fidelity of harlequin ducks, it cannot be assumed that the population in oiled areas will return to pre-spill levels. In fact, the population may continue to decline because of a lack of recruitment and limited immigration. It is necessary both to continue monitoring population and reproductive trends, and identify factors limiting recovery.

The goal of this project is to continue monitoring the harlequin duck breeding population and annual productivity. Proposed surveys will provide trend indices to assess recovery of resident populations of harlequin ducks and determine factors inhibiting or contributing to recovery and restoration. Specific information on habitat associations and structure of the breeding population will provide a measure of recovery or guide development of further investigations. Technical information is applicable to evaluating habitat acquisitions and intertidal habitat restoration projects that benefit a variety of species (e.g. shorebirds, sea otters).

NEED FOR THE PROJECT

Regardless of ultimate causes, collective results of EVOS studies indicate serious population-level concerns for harlequin ducks in western PWS. Prompt focus on specific population parameters is necessary to determine the status and recovery potential of harlequin ducks. Sea duck populations, in general, are composed of long-lived birds that have delayed sexual maturity, low annual production rates, and "boom and bust" years. Consequently, sea duck population dynamics are quite sensitive to adult survival rates, size of the breeding component, and variable breeding propensity (% of adults breeding annually). Data on sex and age composition are very useful in examining these aspects of a population. To date, EVOS projects have gathered abundance and distribution data only on total harlequin ducks, with little information on sex and age composition, or proportions of paired birds. The focus of these projects has been extensive survey coverage and a diverse array of other time-consuming objectives. Also, efficient techniques for the kind of intensive survey required have not been developed for sea ducks.

Currently, there are no sufficiently measured parameters of harlequin population dynamics with which to construct a population model for Prince William Sound. A reliable breeding bird survey is a critical prerequisite to evaluating the remaining reproductive potential in the western Sound and acquiring data to fill in several important model elements. The survey described below is intended to establish quantified restoration goals and implement an effective monitoring program for harlequin ducks in PWS.

Evidence of oil ingestion and physiological effects on harlequin duck reproduction have been investigated through 1993. Some intertidal sites remain contaminated. Nearshore studies (NOAA-NMFS) of intertidal zone recovery and contamination of invertebrates are a vital corollary to the harlequin duck project.

PROJECT DESCRIPTION

A. Objectives

The objectives of this study are to: (1) document abundance, distribution, and age-sex structure of the pre-nesting population in PWS through May-June breeding bird surveys; (2) document annual harlequin production and post-breeding abundance in the EVOS region through brood and molting surveys; (3) Classify streams and shoreline habitats in western Prince William Sound to correlate habitat parameters with eastern Prince William Sound; and (4) pending 1993 results of contaminant analysis of harlequin duck tissues and blood chemistry, document continued exposure of sea ducks to oil and physiological links to reproductive impairment through blood and tissue sampling.

B. Methods

This project uses established methodology including boat surveys of shoreline and suitable breeding streams during May-June throughout PWS, and molting and brood rearing habitats during July and August. Sex-age classification methodology currently being developed will be used to determine population structure during spring and summer surveys. Results from the oil spill area will be compared to 1990-93 results and to data collected in unoiled areas of eastern and southern PWS. Habitat use associations will be recorded during both surveys and integrated with a database being developed from previous work.

Contingent on 1993 results indicating evidence of continued oil ingestion by harlequin ducks or physiological anomalies related to reproduction, an effort may be mounted to sample blood and/or tissues from breeding harlequin duck in 1994 and contract for analytical services. Blood samples could be analyzed for normal blood parameters and abnormalities. Presence of elevated levels of haptoglobins and interleukins in blood sera or positive P450 enzyme activity may indicate continued petroleum exposure if statistically correlated to the oil spill area.

C. Schedule

The course of this monitoring program is projected for five years. Survey schedules are in accordance with the draft EVOS Restoration and Monitoring Plan. This project will be conducted during the 1995 field season, with survey effort focused on May-June and July August periods. Interim analyses and reporting will occur throughout 1995 and early 1996. Contract laboratory analyses should be completed by December 1, 1996. Report preparation will begin in September, and a progress report will be completed before January 30, 1996.

D. Technical Support

If warranted, Dr. D. M. Fry will provide blood chemistry interpretation following analysis of clinical chemistry by California Veterinary Diagnostics, perform plasma electrophoresis for

evidence of protein changes, and provide histologic interpretation of tissues. NOAA-NMFS Auke Bay Laboratory is the preferred source for hydrocarbon analyses of any food items and tissues that are collected. Videography to aid in population structure will be contracted.

E. Location

The proposed project will be conducted in the oil spill area of Prince William Sound and unoiled eastern PWS from Valdez to Cordova. Communities affected by the project include Chenega, Whittier, Valdez, and Cordova.

PROJECT IMPLEMENTATION

This study will be conducted and managed by the Division of Wildlife Conservation, Waterfowl Program, under supervision of the Waterfowl Coordinator. The Alaska Department of Fish and Game has been conducting EVOS harlequin duck investigations and monitoring since 1989. Data collection will be accomplished by Division staff during field periods, with data analyses and reporting assigned to appropriate project participants. The Waterfowl Coordinator will be responsible for administrative and technical aspects of the project, including planning and budget preparation, tracking expenditures, personnel assignments, contract oversight, and quality control of products.

Data collection will be controlled by employee training, supervision and compliance with methods and techniques described in SOPs. Chain-of-custody procedures as outlined in State/Federal Damage Assessment Plan: Analytical Chemistry QA/QC are being followed. Samples and data will be archived at the Department of Fish and Game. The products of this study will be interim and final reports with maps, figures, and tables.

Costs of tissue analysis for petroleum exposure are paid through a contract with NOAA Auke Bay Laboratory. An RSA will be issued for technical support on Harlequin Ducks at University of California, Davis. Costs of videography and editing will be contracted, source to be determined.

COORDINATION OF INTEGRATED RESEARCH EFFORT

There are no other projects directly related to the work planned in this project, although results may be integrated with USFWS boat surveys for birds and mammals and NMFS intertidal invertebrate surveys. Techniques developed on this project will provide a basis for future monitoring efforts for all sea ducks. Subsequent EVOS program development can incorporate sea duck population dynamics information with intertidal and nearshore ecosystem projects.

FY 95 BUDGET (\$K)

Personnel	141.2
Travel	8.1
Contractual	24.5
Commodities	18.2
Equipment	12.0
Subtotal	204.0
Gen. Admin.	22.9
Total	226.9

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Data Analysis for Stream Habitat

Project Number:	95505B
Restoration Category:	Habitat Protection (continuation of 94505)
Proposed By:	USFS
Cost FY 95:	\$17,200
Cost FY 96:	\$0
Total Cost:	\$17,200
Duration:	1 year
Geographic Area:	Prince William Sound, Kenai Peninsula, and Kodiak Island Area
Injured Resource/Service:	Multiple resources

INTRODUCTION

Preliminary data collected on the Kenai Peninsula suggests that channel types, as defined from aerial photographs, may be a predictor of at least several micro habitats found in a stream channel. A multivariate analysis of variance indicated that channel types were a significant predictor ($P < 0.0001$) for eight of thirteen microhabitats (e.g., rapids, plunge pools, and dammed pools). Further data collection for the Oil Spill Trustee Channel Type Classification Study indicated that channel types are also a significant predictor of the amount of spawning and rearing habitat in a given segment of stream.

NEED FOR THE PROJECT

Rates of salmon mortality are highest during their early stream-dwelling life stages. Because mortality is often related to the condition and availability of in-stream habitat, it is critical that habitat limiting to juvenile salmon be protected or restored. Basin-wide in-stream habitat surveys are essential to predict those habitat conditions that limit survival. In remote areas of Alaska it is impractical to physically survey all streams within a given drainage, therefore, a hierarchical approach that lends itself to photo interpretation would greatly increase the efficiency of large scale habitat inventories.

PROJECT DESIGN

A. Objective

1. Complete data analyses and professional publication for an existing stream habitat data base.
2. Establish the relationship between channel type designations and the presence of in-stream micro habitat (spawning and rearing).

B. Methods

Existing data bases will be analyzed to firmly establish the relationship between aerial photo channel type interpretation, and the presence of in-stream habitat (spawning and rearing). In addition, results will be published in a professional fisheries management journal. These analyses and the publication will serve as a basis for any larger scale in-stream habitat surveys that are tied to the Channel Type Classification Study and habitat protection proposals.

C. Schedule

Data analysis and report preparation will be performed during January through April 1995.

D. Technical Support

None.

E. Location

Data for Prince William Sound, Kenai Peninsula and Kodiak Island Area streams will be analyzed. Data analysis and report preparation will occur in Anchorage, Alaska.

PROJECT IMPLEMENTATION

This project will be implemented by USFS personnel.

COORDINATION OF INTEGRATED RESEARCH EFFORT

This project is an extension of previous projects designed to provide comparative evaluations of fish habitat within comparative evaluation parcels.

FY 95 BUDGET (\$K)

Personnel	10.4
Travel	0.0
Contractual	4.0
Commodities	1.0
Equipment	0.0
Subtotal	15.4
Gen. Admin.	1.8
Total	17.2

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Attn: Comments on Draft FY 95 Work Plan

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