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Fiscal Year 1996 Work Plan

Detailed Project Descriptions

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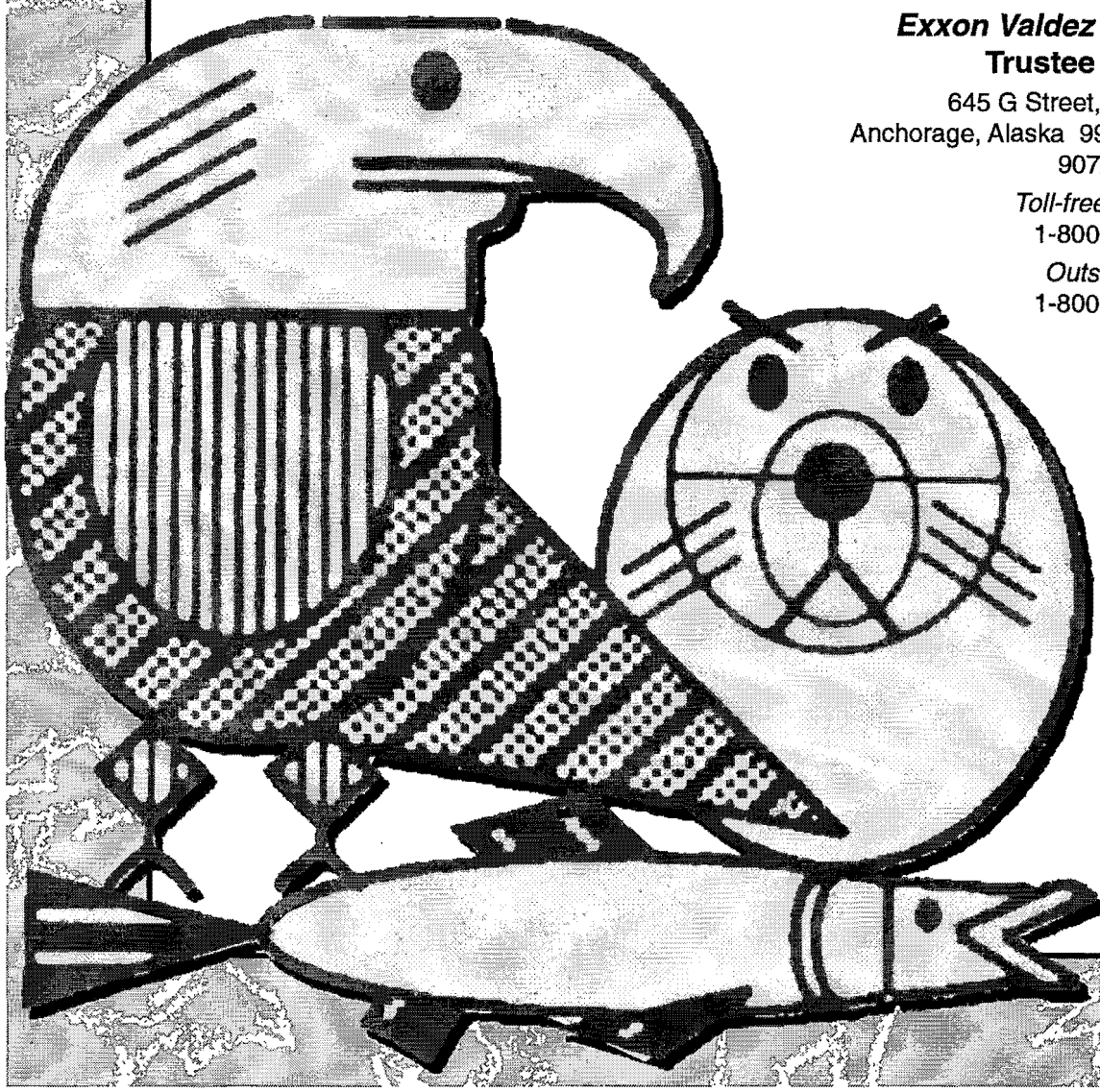

April 1996

FY 96 WORK PLAN -- INDEX OF DETAILED PROJECT DESCRIPTIONS

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96001

Recovery of harbor seals from EVOS: Condition and health status.

Project Number:	96001
Restoration Category:	Research
Proposer:	University of Alaska, Fairbanks
Lead Trustee Agency:	ADF&G
Cooperating Agencies:	NONE
Expected Duration:	3 Years
Cost FY 96:	$214,100
Cost FY 97:	$192,300
Cost FY 98:	$ 48,100
Geographic Area:	Prince William Sound
Injured resource:	Harbor seals

ABSTRACT

This project focuses on the health of harbor seals, a marine mammal species that is not recovering in Prince William Sound (PWS). Personnel from the University of Alaska in cooperation with the Alaska Department of Fish and Game will work with harbor seals to assess their health, blood and blubber chemistry and size in relation to their ecological and nutritional requirements. The project addresses potential health and nutritional problems that may be impeding harbor seal recovery.

INTRODUCTION

This proposal is a multi-year combination and extension of projects 95001 and 95117-BAA which were approved for funding in FY 1995. It deals with body condition and health indices of harbor seals (Phoca vitulina) in Prince William Sound in relation to their non-recovery status. The central hypothesis of the proposal is that given the poor population status of harbor seals in the impacted area, do the animals show signs of health, nutritional or body condition deterioration that could be contributing to their poor recovery?

The project is written with significant logistical and scientific collaboration from project /064 which deals with monitoring population levels, habitat use and trophic interactions of harbor seals. Project /064 provides access to the animals and a broad based ecological view relevant to harbor seals in this

geographic area. The goals of the combined collaborative projects are to investigate ecosystem wide questions addressing the recovery of harbor seals. These issues include the direct impact of oil spills, human interactions, food, competition, climatic factors, disease and habitat loss. 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 and food limitation. It specifically addresses the health and food limitation hypotheses as outline in the marine mammal section of the the FY 1996 Draft Restoration Program.

Project 95001 was approved to begin funding on January 1, 1995. It deals with body condition and blood chemistry indicators of nutritional problems, disease and growth for harbor seals inside and outside of PWS. This project works in critical collaboration with project 95064 and other non-Trustee Council funded programs. The University of Alaska provides personnel to take blood and blubber samples and to measure and weigh the seals. Blood and blubber samples are analyzed at UAF and models of body shape, blubber thickness and body condition are generated and tested. Appropriate control samples in time and space have always been a concern for this project. In an effort to control for this, we have set up identical sampling protocols in collaboration with ADF&G for working with harbor seals OUTSIDE of PWS. Thus, we have harbor seal data from southeast Alaska and from around Kodiak for control purposes. Since initiation of 95001 we have worked with harbor seals on the west coast of Kodiak and are preparing to receive samples from the Juneau area in late April and to work with 95064 in PWS in early May.

Project 95117-BAA was approved by the Trustees in October, but will not begin funding until May, 1995. This was a special project to examine blubber chemistry in harbor seals both inside and outside of PWS as noted above and to examine historical samples of blubber collected from before the *Exxon Valdez* (EVOS) event. The central hypothesis of this project is that since seals utilize fat and blubber as their primary energy source, then alterations in blubber chemistry should reflect nutritional problems in the seals. Because this project has not yet received funding, no work has been done to date.

Finally, it is critical to understand that our laboratory is involved in general determinations of seal and sea lion health in pinniped populations from around the world. We work on similar questions in regions far removed from PWS and on many different species in an effort to understand relationships between ecological health, nutrition and body condition of marine mammals. For UAF, the PWS/EVOS question is part of a broad study about adaptations of marine mammals to their ecosystem. We test theories on blood chemistry and body condition in marine mammals on a daily basis from a host of different species collected from a wide geographic area. These EVOS projects provide opportunities for us to test our comparative theories of marine mammal health and to provide the Trustee Council with the data they need for issues concerning recovery in PWS.

NEED FOR THE PROJECT

A. Statement of problem

Harbor seal (Phoca vitulina) populations in Alaska show evidence of decline over portions of their

range. Prior to the EVOS event, population declines of 85% had been reported from Tugidak Island (Pitcher 1990), and declines may also have occurred in the eastern Bering Sea and Aleutian Islands (Hoover-Miller 1994). Prince William Sound harbor seal populations, further impacted by EVOS (Frost and Lowry 1994a), have essentially stabilized at decreased levels, but have shown no signs of population recovery (Frost and Lowry 1994b). Trend-site counts in PWS indicated that declines occurred both in pup and non-pup portions of the population (Frost and Lowry 1994b). Assessment and interpretation of harbor seal body condition, blubber chemistry and nutritional status data can help resolve multiple hypotheses proposed to explain these declines, and to help focus future studies.

B. Rationale

Changes in ecosystems or in prey availability due to natural or anthropogenic causes can be reflected in the body condition or nutritional status of top trophic-level consumers, such as harbor seals. However, indices used to assess body condition may also vary with season, age, or sex (Pitcher 1986; Trites and Bigg 1992; Beck et al. 1993; Renouf et al. 1993) independent of foraging ability or prey availability. Therefore, normal ranges of body size, shape and blubber chemistry distribution must be quantified before useful inter-annual comparisons can be performed. Likewise, blood chemical and hematological parameters also change significantly in response to environmental or nutritional effects (Seal et al. 1975; Geraci et al. 1979; McConnell and Vaughan 1983; Kuiken 1985; Roletto 1993). Chemical profiles and complete blood counts can identify potential imbalances in organ systems or metabolic pathways if the effects of non-health related variation can be quantified (Payne and Payne 1987; Kerr 1989; Castellini et al. 1993).

C. Summary of major hypotheses and objectives

This proposal specifically addresses the Draft Restoration Plan hypotheses that harbor seals are not recovering in the EVOS impacted area due to nutritional and health related problems.
The working hypothesis is that either the EVOS-impacted seals are different in their health status compared to non-EVOS animals, or they are not. If the PWS harbor seals are compromised, then we will know some of the directions that should be followed towards potential restoration. If they are not compromised, then we can focus our attention into other areas that may better explain their current recovery status. The objectives are to assess health and body condition from animals inside and outside of the EVOS region and to examine historical samples to analyze potential differences over time.

D. Completion Date

This project is scheduled to finish field work by the fall of 1997 (FY 1997) with close out during 1998 (FY 1998).

COMMUNITY INVOLVEMENT

Results of this study will be presented at appropriate EVOS workshops, as well as at professional meetings such as the Biennial Conference on the Biology of Marine Mammals to be held in winters

of 1995 and 1997. There are no sections of the project that would easily involve residents of the spill-area communities. The work is either at-sea collection of seals or laboratory and computer analysis of data.

PROJECT DESIGN

A. Objectives

Given the combination of projects /001 and /117BAA in this continuing proposal, the objectives have been combined as follows:

1. Collect hematological data to establish reference ranges of blood chemistries and hematologies of harbor seals inside and outside of PWS and determine variation attributable to sampling technique, age, sex, or season and location of capture.

2. Estimate our ability to detect changes in body condition using morphometric measurements.

3. Assess body condition using morphometric measures of body shape, density and fat content, and determine the effects of age, sex, season and location.

4. Compare blood and morphological indices of health and condition in light of the above to examine interannual changes, potential EVOS-related impacts, and to help interpret changes in population status.

5. Obtain blubber samples from contemporary animals inside and outside of PWS for energy analysis and compare these findings with archived samples.

B. Methods

Seals will be captured during spring and fall of each year. Laboratory analyses and statistical analysis will be conducted throughout the remainder of the year.

Field Techniques. Harbor seals will be live-captured by net entanglement, in conjunction with EVOS Project Number \064, using methods previously described by Frost and Lowry (1994b). Once captured, seals will be transported to shore or ship, anaesthetized if required (using Ketamine and Diazapam), weighed with an electronic hanging scale, and morphometric measurements gathered. Blood will be drawn from the extradural vein into Vacutainer® blood collection tubes.

Body Condition. Linear and curvilinear length, a series of girths at 7 locations, and mass will be collected from each animal. Blubber depths at 2-3 sites at each girth ring will be measured using a portable ultrasound unit (Scanoprobe II, Model 7310, Scanco, Inc.). These measurements are quickly and easily carried out in the field. In the laboratory, the data will be fit into models of how length, girth and mass are related for harbor seals and will be used to evaluate body condition.

Additionally, measurements of total body impedance (BIA) will be made opportunitsically by recording the resistance across two pairs of electrodes placed near the seal head and tail, allowing estimation of body fat. Condition indices will be compared using a database of morphometric measurements and corresponding body and sculp masses collected during 1972-1978 by Alaska Department of Fish and Game, and previously presented in Pitcher and Calkins (1979) and Pitcher (1986).

Hematology. Blood hematocrit (% red blood cells by volume) will be measured in the field using a portable centrifuge. Samples will be transported to the ship/lab and examined microscopically to determine red and white cell counts. Samples of whole blood will be pipetted into Drabkin's reagent for hemoglobin analysis. Subsamples of blood will be centrifuged to prepare plasma and plasma, serum and whole blood samples will be frozen in liquid nitrogen for later laboratory analyses. Plasma samples will be 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 our lab for indicators of dehydration (water content), malnutrition (BUN, ketones), acute phase reactions (haptoglobin), hormone imbalance (angiotensin, ANP) and stress proteins (samples sent to collaborators at Stanford Research Institute). Standard panels that assay plasma sodium, potassium, chloride, phosphorous, creatinine, cholesterol, direct and total bilirubin, total protein, albumin, globulin, alkaline phosphatase, glucose, lactate dehydrogenase, gammaglobulin transferase (GGT), creatinine phosphokinase (CPK), aspartate aminotransferase (SGOT) and alanine aminotransferase (SGPT) will be performed by automated machine analysis at the Fairbanks Memorial Hospital (FMH) using an Ektachem Analyzer. Additionally, concentrations of free fatty acids (FFA), ketones (β-HBA), uric acid, iron, blood urea nitrogen (BUN) and hemoglobin will be determined using standard kits from Sigma Chemical Co. and performed in our laboratory. Complete blood counts of white and red blood cells, platelet and differential white blood cell counts will be performed by technicians at FMH from blood collected in EDTA vacutainers using a Coulter Model S-Plus-4 Counter, and from blood smears produced in the field.

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 databases and the consistency to best analyze these samples from the PWS and non-EVOS animals. Statistical comparisons of hematological values, body condition and shape will be performed using PC-based software. The ultimate goal is to derive useful indices of condition and hematology, that when controlled for other sources of variation such as sex, age and season of capture, will enable interannual comparisons of nutritional and health status.

Blubber chemistry. Additional testing of the food limitation hypothesis will be accomplished by comparison of blubber quality between archived, historical blubber samples collected during the mid-late 1970's, to blubber samples biopsied during current research projects inside and outside of PWS. The determinations described below completely quantify the energetic state of blubber in terms of its potential as a fuel source. Our hypothesis is that since blubber is a major component of the body tissues of seals (27-30% of body mass (Pitcher 1986)), contains 90% of the lipid fuel sources in seals (Beck et al. 1993), and lipid utilization makes up approximately 85% of the energy utilized by seals (Ryg et al. 1990), then changes in the lipid content, blubber density and energy content should reflect

seasonal and interannual changes in body condition of the seals. It is known that the blubber content of an animal and the lipid content of blubber varies with season, age and sex (Pitcher 1986; Ryg et al. 1990; Beck et al. 1993). The archived historical blubber samples have complete data sets on animal condition associated with them, and these data are also collected for the contemporary animals.

Collection of historical samples. Alaska Department of Fish and Game has archived, frozen samples of harbor seal blubber collected well before the EVOS event that are available for this analysis. They have given us permission to utilize this collection if personnel from UAF can travel to Anchorage to transfer and collate the samples. About 250-300 samples are archived.

Collection of contemporary samples. Blubber samples will be acquired from live animals captured in conjunction with Project No. 95064 and other non-oil spill related projects. Blubber samples will be collected by tissue biopsy using standard techniques already being employed. In the field, biopsy samples will be placed in cryovials and frozen at -80 °C in liquid nitrogen dry-shippers for transport to the laboratory.

Analysis of blubber. Samples of blubber will be analyzed for quality and density of energy. Four specific tests will be conducted on each sample:

1. Density of blubber.
2. Total lipid content of blubber.
3. Hydration state of blubber.
4. Total energy content of blubber.

Blubber density will be determined by simple mass and volume measurements of blubber samples. Total lipid content of blubber is determined by organic extraction of lipids using a Soxhlet apparatus and standard extraction techniques. Blubber hydration state is determined by mass difference between wet and dry weights of samples dried in a drying oven. Finally, the total energy content of blubber is determined by bomb calorimetry of the sample to determine calories available. Historical specimens will be closely examined for signs of dehydration or oxidation (freezer-burn), and either subsampled from acceptable sites, or rejected. Because phocid blubber lipid content is homogenous both in location on the body and depth of sampling (Jangaard and Ke 1974; Beck et al. 1993), variability in sampling site should not confound analyses. One-way and multi-factorial analyses of variance will be performed to assess the affects of age, sex, season and year on these measures of blubber quality. Morphometric data available from the historical animals and from those sampled currently will enable calculation of total blubber energy stores for these same comparisons.

Potential analytical difficulties. Blubber samples store for long periods may be subject to deterioration and oxidation, depending on storage techniques and temperature. Dehydration would directly impact water content and density analysis, but should not alter the lipid analysis or bomb calorimetry since samples are freeze-dried for those procedures. However, interpretation back to a wet-weight basis would be problematic. Historical samples will be examined for sign of dehydration and subsamples taken as far away from the edges as technically feasible. Significantly dehydrated samples will be rejected. We will also use control samples of recently collected blubber from harbor

seals and other species to determine wet-mass to dry-mass ratios, and compare these to values measured from archived samples to index hydration. If some of the samples are dehydrated, then lipid and energy content will be compared to recent samples on a dry-weight basis only. It is also possible that because phocid blubber is typically less than 3% water (Beck et al, 1993), minor dehydration will not significantly effect results.

Oxidation of samples during storage can alter lipids by reducing molecular chain length. This would prohibit fatty acid identification, and we are not attempting these assays. However, oxidation of lipid chains also reduces the energy content by a percentage of the chain length that has been lost. We will minimize this problem by utilizing close inspection and rejecting blubber samples that appear massively oxidized and from which we cannot sample in undamaged areas.

When project 95117 was originally reviewed, there was considerable discussion between the referees, the Chief Scientist and our laboratory about how to handle the sample deterioration problem. We consulted with lipid and tissue specialists around the country and the world and defined the protocol listed above. Unfortunately, the start date of 95117 occurs after this proposal was written and preliminary data are not yet available.

C. Contracts and other agency assistance.

No contracts with other agencies are anticipated. Collaborative work with project \064 is critical to this project, but this is not on a contract basis. Bomb calorimetry of the blubber samples is on a per-sample basis to another lab at UAF.

D. Location.

Harbor seals will be captured from haul-out locations within PWS including sites which varied from non-oiled to heavily-oiled during the EVOS. Our laboratory also collects data from harbor seals outside of PWS for comparative purposes.

SCHEDULE

A. Measurable project tasks for FY 96

Generally, field work occurs in the spring and fall seasons with laboratory and statistical analysis occuring year round.

For FY 1996 and FY 1997:

October:	Analysis and statistical study of fall blood samples.
November:	Collection of archived blubber samples.
December:	Analysis of blubber water content.
January:	Winter EVOS workshop.
January:	Preparation of blubber samples for bomb calorimetry.

February: Modeling of body morphometrics.
March: First collection of field samples outside of PWS.
April: Analysis and statistical study of blood samples.
April: Second collection of field samples outside of PWS.
April: Annual report.
May: First collection of field samples inside PWS.
June: Analysis of all blood samples.
June: Summer EVOS workshop.
July: Modeling of body morphometrics and blubber data.
August: Modeling of body condition indices.
September: Second collection of field samples inside PWS.
October: Third collection of field samples outside PWS.

For FY 1998:
October: Analysis and statistical of fall blood samples.
Nov - Dec: Modeling of body condition.
January: Winter EVOS workshop.
Feb-closing: Publication preparation, final reports, presentations.

B. Project milestones and endpoints

Each project objective involving field work is an ongoing operation inside the time-frame of this proposal. However, the section dealing with collection of archived blubber samples should be finished by the end of FY 1996. Each field season is of a specific duration and has very controlled beginning and end points, but analysis of the data is continually updated with information on other species and other locations. Results of each field season will be presented in annual reports as noted below.

C. Project reports

We assume that annual reports will be due each April, just before the major field season for work inside PWS commences. This should allow maximum time for determination of field work that started the year before. We will work with the chief scientist to determine if publications in peer-reviewed journals will act in the place of a separate report. We also assume that a final report will be submitted at the end of FY 1998.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

As noted before in the body of the proposal, this project has a critical collaboration with project \064 and with other ADF&G projects outside of PWS. Without \064, we would not have access to seals and would not have the ecological based data necessary for successful interpretation of our results. The work by other ADF&G projects outside of PWS are also essential for our comparative work with harbor seals so that we can model changes in oiled vs non-oiled areas. Collaboration with ADF&G to obtain the archived blubber samples is also essential to the project.

We are currently finishing a National Science Foundation project looking at health indices of seals that utilizes many of the same analytical and statistical techniques as this proposal. This project should finish by December, 1995. We have also submitted a large Alaska Sea Grant proposal (to initiate February 1996) to look at the health status of harbor seals, Steller sea lions and ringed seals in Alaskan waters. We will be working in Alaskan waters with National Marine Fisheries Service support on Steller sea lions to examine health issues relative to the severe decline in this species. We will be collaborating with post-doctoral staff at the National Marine Mammal Laboratory on issues of blood chemsitry values in seals and sea lions.

As noted above, we are a comparative laboratory that has a broad interest in the physiology, bio-medicine and ecolological physiology of seals and sea lions. The opportunity to work with EVOS impacted animals expands our abilities to look at specific instances of pinniped health, nutritional and to provide the Trustee Council with the data they need for restoration purposes.

ENVIRONMENTAL COMPLIANCE

This issue has already been covered by the initiation of 95001 and the potential initiation of 95117.

Archaeological Index Site Monitoring, FY 96

Project Name:	96007A
Restoration Category:	Monitoring, continuation
Proposer:	Alaska Office of History and Archaeology, ADNR
Lead Trustee Agency:	Alaska Department of Natural Resources, ADNR
Cooperating Agencies:	U. S. Fish and Wildlife Service, DOI-FWS U. S. Forest Service, USFS
Duration:	4 years
Cost FY 96:	$141,600
Cost FY 97:	$135,000
Cost FY 98:	$145,000
Cost FY 99:	$135,000
Geographic Area:	Prince William Sound, Kenai Peninsula, Kodiak Island
Injured Resource/Service:	Archaeological Resources

ABSTRACT

Monitoring of archaeological sites on public land injured by vandalism and oiling will concentrate on a sample of index sites in the three regions of the spill. Oiled sites will be tested for re-introduced oil. The ten year project will end at five years if monitoring shows no continued injury.

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. Damage from vandals has continued to be documented at several sites on public lands during the past several seasons. Although other sites have not suffered damage, vandals are still active in the area and their level of activity needs to be monitored. Monitoring of damaged sites as a gauge of vandal activities in the spill area was identified as a primary strategy for site restoration during 1995 and is being continued to provide a long term assessment of the problem. A consensus was reached among agency archaeologists that the most

efficient way to monitor vandalized sites would be to select "index" damaged sites to provide an indication of the level of vandal activity in the spill area.

A recommendation of the Trustee's archaeological peer reviewer during the January 1995 science workshop was to continue to monitor oiled sites on an intermittent basis. His concern was that subsurface oil would move into archaeological deposits and compromise possible data recovery.

Monitoring of archaeological sites injured by the spill or spill related activities will target a small number of sites on public lands which are determined to represent those that are most vulnerable to looting or oiling. Those index sites will serve as a gauge for levels of vandalism in the spill area. The index sites oiled during the early time immediately after the spill in March 1989 will be re-checked during 1996 and subsequent years to detect recent infiltration of subsurface oil from surrounding sediments. Sites in the Prince William Sound area include SEW-469 and SEW-077. Outer Kenai Peninsula sites are SEL-129 and SEL-025. Sites in the Kodiak Island archipelago include KOD-171, AFG-129, AFG-097, and AFG-046. See attached site locations map.

NEED FOR THE PROJECT

A. Statement of Problem

Sites monitored under project 96007 are index archaeological sites thought to be representative of archaeological sites on the public lands in the spill area which have been oiled or are being vandalized. Some sites were oiled during the spill and are being monitored to check for recent movement of subsurface oil into site deposits.

Vandalism during cleanup appears to have been associated with people placed near sites while living on chartered boats. Circumstantial evidence indicates that some crew members, many of whom were residents of coastal communities, were involved in looting of sites. Agency resource managers fear that looting associated with cleanup continued on and spread to other sites of the area.

Oil was found in beach sediments at several of the sites selected as index localities although none was initially documented in site deposits. A goal of this project is to monitor those sites to detect movement of the persistent oil into cultural deposits from the surrounding sediments.

B. Rationale

Loss of sites to vandals and pollution of sites from remaining oil removes the ability of archaeologists to recover data about the prehistory from those sites. The number of sites in the area is finite and will not increase. Reasonable efforts must be made to protect the cultural heritage data base from degradation. Sites in the area continue to be lost to erosion, making loss from this human degradation more critical.

Monitoring and testing for oil contamination is the most efficient way to gain knowledge about continuing data loss. Through knowledge gained over a period of observation, land managers can devise methods of saving the data or at least slowing the rate of loss.

C. Summary of Major Hypotheses and Objectives

The major objective of the index site monitoring project is to protect sites in the spill area from loss to looters and encroaching subsurface oil. The continuation of both processes has been well documented in earlier studies. The method of achieving that protection is to monitor a sample of known area sites so that management plans can be devised to insure protection of the remaining sites. Continued monitoring is thought to be the most cost effective way to identify critical developments and respond.

D. Completion Date

Monitoring oiled and vandalized years has been proposed to continue for a period of ten years, FY 95 through FY 2004. Funding during FY 95 for monitoring was provided to land managing agencies to begin the process. Funding during FY 96 will allow return to three sites visited during 1995 for continuous monitoring and visits to five other sites to be monitored on an intermittent basis. A report of annual activities is projected with a cumulative progress report proposed for FY 98. A final assessment report will be prepared after the ten year monitoring program ends in FY 2004. The project could be terminated at the progress report in FY 98 if injuries have diminished to an insignificant level.

COMMUNITY INVOLVEMENT

The sites identified for attention in this proposal are remote from most communities with the exception of the SEW-077 site near Chenega Bay Village. The Forest Service which has proposed monitoring at that site will be coordinating with the Chenega people. Communication with other Native groups will include sharing information about findings. Communication with most community groups about the project will be minimal because of the sensitive nature of site locations.

PROJECT DESIGN

A. Objectives

The overall intent of the archaeological site monitoring program is to maintain a current assessment of the status of vandalized sites in the oil spill area and sites oiled during the spill. Continuing and current site status is required to protect the sites from degradation. The objectives of the FY 96 project are:

1. Monitor vandalized sites to identify continuing vandal activity in order to protect the sites. Information about index sites will be projected for management planning to the larger inventory of sites in the spill area.

2. Monitor sites contaminated by oil during the Exxon Valdez Oil Spill to identify any encroachment of subsurface oil into the cultural deposits from surrounding sediments.

The intent of the project at its conclusion is to have maintained a presence at the vandalized sites for a long enough period of time to gauge levels of vandalism and discourage that activity by our presence. The long range intent by FY 2004 is to reduce that activity to zero. Oiled sites will be considered restored when they have remained oil free for the life of the project. Oil in surrounding sediments will be considered stable or immobile by that time.

B. Methods

A strategy was identified during a 1994 restoration workshop of designating index sites vulnerable to looting which will be monitored on an annual basis. A second group of four sites were identified which are to be monitored 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. Sites which were oiled will be monitored for oil so the behavior and effect of oiling can be observed over the long term in archaeological deposits.

Testing for presence of oil in site sediments will be done with the HNU-Hanby field test kit which can identify the presence of petroleum hydrocarbons and give an estimate of the relative concentration of the contaminants in the soil. Once the field tests show positive for oil, plans will be made to obtain funding so that the Auke Bay lab can send personnel to collect suitable samples for identifying the source of the oil and more accurately determine the amount present. This procedure was suggested by Auke Bay lab representatives at the 1995 work plan session so that suitable samples could be properly collected and processed.

Documentation of site status at the localities monitored for vandalism will include re-locating previously established reference points and referring all observations to those points. Field maps will be drawn or surveyed as appropriate. Photo and video documentation will be referenced to datum points and will duplicated earlier perspectives as closely as possible. Test localities will be mapped in reference to site reference points.

SEL-025 The historic cabin site near the head of the West Arm of Port Dick will be returned to in FY 96 to assess the current status of oiling and effect of bioremediation on the site. Beach deposits immediately adjacent to the cultural remains were treated during 1990 at which time ADNR archaeologists thoroughly mapped the site.

SEL-129 The house depressions of the Gore Point Village Site were impacted by erosion of the vegetation cover through establishment of trails during cleanup activities. Trails were worn into the

vegetation cover by workers traveling from the west beach at Gore Point to the east beach. The site will be visited by ADNR during FY 96 to assess the current status of the site and see if the eroding depression walls have degraded further.

SEW-077 The Forest Service will monitor at the SEW-077 Site which was oiled during the Exxon Valdez Oil Spill. The beach sediments at the site will be tested with the HNU-Hanby Field Test Kit to measure for presence of subsurface oil. The Chenega Village Corporation will be contacted by the Forest Service to establish cooperation on the activities.

SEW-469 The SEW-469 Site will be returned to during FY 96 to be examined for any additional vandalism. The site is scheduled for monitoring during 1995 by U. S. Forest Service archaeologists. Human remains were disturbed by vandals during cleanup and were re-interred.

Perevalnie Passage Site, AFG-046 A return visit to this site will have two objectives. First, the site will be examined to detect whether vandal activity has continued or accelerated over past levels. To that end, a map detailing location of artifacts and bone exposed along with areas of disturbance will be taken into the field to compare with current findings. Photographic reference points will be re-established, and photographs comparable to 1993, 1994, and 1995 will be taken. A detailed map locating the erosional face will be made to detect rates of erosion and vandalism for future monitoring visits.

Second, a series of test excavations will be made in the intertidal area where the SUNY-Binghampton field team documented peat deposits. That will allow re-testing for subsurface oil to check for migration of the contaminant. The HNU-Hanby field test kit will be used to screen for the presence of petroleum hydrocarbons and provide some measure of concentrations. If petroleum hydrocarbons are present then the location will be recorded with reference to a permanent datum point. The location will then be re-visited during the next season to obtain proper samples to identify the source.

AFG-097 Reports have been received that this site has been vandalized and the damage should be monitored as part of the oil spill vandalism monitoring. The site has experienced significantly increased use since the Exxon Valdez Oil Spill. The site is very near the vandalized AFG-081 which is slated for monitoring in 1995. A quick field map will be prepared and reference points selected to measure developments.

AFG-129 The Ban Island Site was vandalized during presence of the cleanup fleet in the area during 1989. Exxon personnel recorded the injury and monitored the site for a brief period at that time. A map was prepared which documented the extent of injury. The site will be re-visited during FY 96 to monitor any recent vandal activity.

Chief Cove Site, KOD-171 The US Fish and Wildlife Service archaeologist will visit the Chief Cove Site to document the present condition of the site as a check for continued vandalism. The agency plans to contact local set net fishermen and other local residents with cabins on private lands nearby to try to educate them about the need for protecting the site. They plan to attempt recruiting the local people to watch the site for them as protection against site vandalism.

C. Contracts and Other Agency Assistance

No major contracts are anticipated in this project. The only contractual activity will be aircraft or boat charters on per hour basis and processing of radiocarbon samples and sediments at commercial labs. Other agency assistance will be in coordination of transportation and field housing by field personnel. Such coordination will be developed as necessary when field activities allow.

D. Location

The sites will be located throughout the spill area. The sites in Prince William Sound are in the area around the north end of Knight Island and on Evans Island. The outer Kenai Peninsula sites are in the Port Dick area. In the Kodiak area, the sites to be investigated are on Shuyak Island, Afognak Island, and in the Spiridon Bay area.

SCHEDULE

A. Measurable Project Tasks for FY 96

Startup (October 1, 1995) - March 1, 1996	Complete requirements for final approval of project including any additional peer review, NEPA compliance (a categorical exclusion expected).
March 1 - June 1	Finalize arrangements for coordination with field people, obtain field supplies, schedule field trips.
June 1 - September 1	Conduct field visits to sites and preliminary reports of activities.
September 1 - October 1	Prepare annual report to Trustees.

B. Project Milestones and Endpoints

The first milestone to be reached in this project will be the visit to the sites identified for FY 96 visits. The second significant FY 96 milestone will be preparation of the agency field reports to be combined into the annual report. The final FY 96 milestone will be submittal of the FY 96 annual report to the Trustees.

Overall project milestones will be completion of annual reports, preparation of a mid-project report in 1998 and preparation of a final report for the 10 year project in FY 2004. The project could be terminated at the proposed mid-point if vandalism and oil damage have diminished to the point of insignificance.

C. Project Reports

Project reports for the FY 96 archaeological site monitoring project will be the annual report submitted at the end of the federal fiscal year, September 30, 1996. During the life of the report, a series of annual

reports are proposed with a cumulative report to be submitted at the half way point in 1998. If the project continues beyond that date, annual reports will continue and a final compilation will be prepared in 2004.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The agency index site monitoring project will be coordinated with the proposed Site Stewardship program in the Kodiak and Outer Kenai Peninsula areas as possible. Travel for the projects will coincide on some occasions and can be combined. The monitoring effort in Prince William Sound will be coordinated with proposed projects expected from the Native communities nearby. Duplication of effort will be avoided.

ENVIRONMENTAL COMPLIANCE, PERMITTING AND COORDINATION STATUS:

The U.S. Fish and Wildlife Service has agreed to file the necessary finding of a categorical exclusion for project 96007. No other permits are necessary as the agency archaeologists will be working on land managed by their agencies.

Site Specific Archaeological Restoration

Project Number:	96007B
Restoration Category:	Restoration management actions; archaeology
Proposer:	Chugach National Forest
Lead Trustee Agency:	USFS
Duration:	1 year
Cost FY 96:	$78,400
Cost FY 97 and future years:	none
Geographic area:	Prince William Sound
Injured Resource/Service:	Archaeological resources

ABSTRACT

Funding is requested for the final phase of the Forest Service's archaeological restoration at sites SEW-440 and SEW-488. Project 96007B, is a continuation of projects 95007B and 94007B. Analysis and interpretation of data gathered during previous field work will result in a peer reviewed final report, prepared and distributed according to Trustee Council procedures. This will complete the restoration process initially prescribed for these sites in 1991.

INTRODUCTION

The proposed phase is the final portion of restoration project previously funded as 94007B and 95007B. Field work accomplishments during summer of 1994 include assessment of the damage documented in 1991 and commencement of the prescribed restoration measures. Restoration was not completed at SEW-488 due to reassignment of the work crew to an urgent Forest Service project towards the end of the field season. That restoration work is scheduled to be completed during the FY 95 field season. The work proposed for FY 96 will complete the restoration project for these two sites. The final portion of the project consists of completing the analysis of various samples, interpreting the data collected, completing the final report through the peer review process, and publishing and distributing the final report.

NEED FOR THE PROJECT

A. Statement of Problem

Project 94007 provided for restoration of two archaeological sites damaged during the Exxon Valdez Oil Spill and its subsequent cleanup program. The restoration measures were recommended by a multi-agency panel of experts in archaeology of the region, chaired by Martin McAllister (1992). The project was designed to effect the proposed restoration measures for each of these two sites. These included a full field site damage assessment, and recovery, analysis, and curation of artifacts for both SEW-440 and SEW-488, with additional backfilling and surface stabilization at SEW-440. Both sites have been treated as being eligible for inclusion in the National Register (Mobley et al. 1990:230), although no formal determination of eligibility has been made for either site. In order to protect and preserve the remaining cultural deposits it is necessary to understand the nature of each site, and the extent to which the identified damage has compromised or destroyed information contained in the sites.

Injury to SEW-440 was described as severe oiling, an increase in erosion of the prehistoric midden component as a result of foot traffic and high pressure water treatment during the cleanup response, displacement of archaeological resources during geological testing, and an un-backfilled excavation in the horizontal surface of the site (Jesperson and Griffin 1992; McAllister 1992). Injury to SEW-488 consisted of oiling, and displacement of archaeological resources during high pressure water treatment and unmonitored cleanup activities (Jesperson and Griffin 1992; McAllister 1992). Erosion along three portions of the site was evident in 1991 (Dekin et al. 1993).

Field work undertaken at SEW-440 in 1994 virtually completed the prescribed restoration field work at the site. A sample taken for monitoring purposes on the southeast shore of SEW-440 in the intertidal zone indicated that fluid oil is still present under 20 to 30 cm of gravel. Despite careful observation, no un-backfilled excavation could be located in the horizontal surface of the site. Erosion is occurring along the pre-1964 beach, and could easily be exacerbated by foot traffic. However, it does not appear to be occurring currently at a high rate, and indeed, it appears that the eroding areas are experiencing natural revegetation. In general, this site seems to have undergone little further disturbance since the cleanup period. Final analysis of the data recovered during testing has not yet been completed, however no further field testing is anticipated during the FY 95 field season.

A beach sample taken for hydrocarbon analysis at SEW-488 showed no obvious evidence of oil in the intertidal zone at this site. However, erosion of the intertidal zone component continues at this time, and several prehistoric cultural items were recovered from the surface of the ITZ. There appears to have been no disturbance of the upland portion of the site beyond what may have occurred during cleanup activities, and during the course of testing for damage assessment. Testing for restoration purposes was not completed during the FY 94 field season and is scheduled for completion during the FY 95 field season.

B. Rationale

Funding is sought at this time for the final analysis, interpretation, report writing, publication and distribution to complete this restoration project as originally proposed. The Secretary of the Interior's Standards and Guidelines for Archaeological Documentation are specific regarding the necessity for a written report to conclude the documentation process, the contents of the report, and its publication and distribution.

C. Summary of Major Hypotheses and Objectives

The major objectives of the project are to ameliorate and halt the deterioration and destruction of the sites to protect and preserve the remaining cultural deposits, and to gain scientific and cultural knowledge which will add significantly to the understanding of the prehistory of Prince William Sound. The results of the project include evaluation of the damaged sites for their inclusion on the National Register of Historic Places, and separate reports geared appropriately for professional archaeologists and for members of the general public.

D. Completion Date

The project will be completed during FY 96.

COMMUNITY INVOLVEMENT

No community involvement in the final report phase of the project is anticipated at this time. However, information which is not considered confidential in nature will be made available to the public as part of the final reporting process.

PROJECT DESIGN

A. Objectives

Project 96007B, is a continuation of projects 95007B and 94007B. The project was designed with two main objectives:

1. Ameliorate and halt the deterioration and destruction of damaged archaeological sites SEW-440 and SEW-488, as prescribed in the McAllister assessment (1991).

2. Protect and preserve the remaining cultural deposits.

B. Methods

The methods used to address the objectives include field work and reporting on the results of the field work. The field work funded under 94007B and 95007B included a full field site damage assessment for each site. This assessment included documentation of the condition of each site through mapping and photography, documentation of the current status of injury, drawing profiles of stratigraphic exposures, and conducting scientific test excavations. This work is completed for SEW-440, and will be completed for SEW-488 during FY 95. Site surface stabilization as necessary will be completed during FY 95, including backfilling of archaeological tests. During FY 96, final analysis of the results of field work will take place, a final report will be written and published, and artifacts will be curated at a Federally approved facility for materials from National Register eligible sites.

C. Contracts and Other Agency Assistance

Specialized professional analysis of archaeological material will be obtained through contracting with private firms which provide such services. This includes analysis of tephra (air-born volcanic ash), pollen, radiocarbon samples, and bone. The printing and binding of the final report will also be contracted to a private firm.

D. Location

The field portion of this project has been and will be western Prince William Sound. Interpretation of results and report writing will take place in Anchorage.

SCHEDULE

A. Measurable Project Tasks for FY 96

October-December:	Analysis of field data and specialists reports
January:	Draft final report to Peer Reviewer and Chief Scientist for review
February:	Revision of final report and resubmission for review
March:	Submission of final report to Oil Spill Public Information Center (OSPIC) for review
April - May:	Modification of final report (if necessary), reproduction, and submission to OSPIC for distribution

B. Project Milestones and Endpoints

Objective 1, amelioration and stopping of the deterioration and destruction of damaged archaeological sites will be complete by the end of the FY 95 field season. The portion of objective 2 which will be

met by test excavations will also be completed at that time, as will part of the analysis. Special analysis reports are expected to be complete by the end of November, and the draft report is expected to be complete by the end of December 1995.

C. Project Reports

As indicated above, a draft final report will be submitted to the Peer Reviewer and the Chief Scientist for review in January 1996. Upon receipt of their comments, the report will be modified as necessary, and resubmitted, as necessary. The finished report will be submitted to the Oil Spill Information Center (OSPIC) in March for format review. After any necessary modifications, the report will be reproduced and bound according to Trustee Council procedures, and submitted to OSPIC for distribution.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Project 96007B is a continuation of projects 95007B and 94007B. The existing Forest Service heritage program does not dovetail with this project. The Forest archaeologists perform fieldwork and related analysis and report writing on a project funded basis.

ENVIRONMENTAL COMPLIANCE

A NEPA review was conducted for project 94007B, which resulted in a categorical exclusion (CE).

96009D-BAA

Survey of Octopuses in Intertidal Habitats.

Project Number:	96009D
Restoration Category:	Research
Lead Trustee Agency:	NOAA
Cooperating Agencies:	Prince William Sound Science Center
Duration:	Three
Cost FY 96:	$142,300
Cost FY 97:	$40,900
Cost FY 98:	0
Cost FY 99:	0
Cost FY 00:	0
Cost FY 01:	0
Cost FY 02:	0
Geographic Area:	Prince William Sound
Injured Resource/Service:	Subsistence resources, intertidal and subtidal organisms, octopus

ABSTRACT

This project addresses concerns that octopus and chiton have been depleted by EVOS and that subsistence uses are impaired. The first year (FY 95) is to establish the feasibility of working on octopus in the Sound, identify suitable study sites, and evaluate techniques. The second year (FY 96) will focus on the vertical distribution of octopus in the nearshore where they are harvested. Close-out costs are requested in the third year (FY 97).

INTRODUCTION

The proposal requests funding for a second year of field work to survey octopus and chiton in nearshore habitats. Work completed during the first year (FY 95) should provide an evaluation of survey techniques, identify suitable study sites through initial surveys and use of local knowledge, and establish

the feasibility of working with octopus in Prince William Sound. The second year of field work is necessary to provide useful data about the dynamics of nearshore populations about which very little is known. The design of the second year survey is left flexible to allow follow-up on findings from the first year.

NEED FOR THE PROJECT

A. Statement of problem

Nearly 90% of the residents of Tatitlek, Chenega Bay, and Cordova used marine invertebrate subsistence resources prior to the *Exxon Valdez* oil spill (EVOS. Seitz, unpublished MS; data on individual species were not presented). Surveys and interviews in Tatitlek and Chenega Bay conducted during the 1980s prior to EVOS indicate that between 50 and 90% of households use octopus as a subsistence resource, while 25 - 50% used gumboot or bidarki chiton. Use of octopus was greater in Tatitlek, where over 1600 lbs of octopus (approximately two octopus per person in the village) were reported harvested in the 1988-89 survey. However, use of chiton appeared larger in Chenega Bay (53% of households vs. approximately 25% in Tatitlek used chiton, Stratton & Chisum 1986, Stratton 1990). A similar survey in Cordova indicated that 1-5% of households use octopus or chiton. Most octopus in Cordova were harvested in conjunction with other subsistence or commercial fisheries, i.e. crab or shrimp pots (Stratton 1989). Harvest is not particularly restricted in season. Chenega Bay harvested chiton primarily from February through April and octopus occasionally from February through August while Tatitlek harvested both these resources in all months of the year (Stratton & Chisum 1986, Stratton 1990).

Octopus and chiton 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. Reduced octopus availability comprises a part of the decline in subsistence services. The extent, severity, and cause of octopus and chiton declines are unknown. It is not known if changes in the abundance of these animals will adversely affect the recovery of other injured resources (e.g. sea otters, harbor seals, intertidal organisms). Without information of this type, the course of recovery cannot be predicted, nor can these resources be managed effectively.

B. Rationale

Restoration goals for subsistence services include healthy populations of subsistence resources, subsistence harvest of those resources, as well as involvement of subsistence users in the Trustee Council's restoration process. This project will provide information regarding the current health of octopus and chiton populations. The project will provide opportunities for the involvement of subsistence users in determining study areas and conducting sampling during minus tides in the intertidal. Information on the results of the research will be provided to Chenega Bay and Tatitlek through community visits by the principal investigator or by other suitable means.

This project will provide an estimate of the availability of octopus in nearshore habitats, the variability of octopus density both between years and among sites, and the status of the octopus population as measured by indicators such as the size distribution of octopus, the frequency of injuries and the turnover rates in different habitats, and the characteristics of occupied habitats and dens in Prince William Sound. The first year of the study (FY 95) is focused on establishing the feasibility of the techniques and identifying suitable study sites. Hence, a second year of field work is necessary in order to provide useful data. This is particularly true for data on interannual variability in density, and for relating turnover and injury rates to habitat types or characteristics.

C. Summary of Major Hypotheses and Objectives

The primary objective is to provide information on the status of octopus as a subsistence resource to subsistence users and resource managers. Study design is targeted on octopus, but data will be collected on chiton as opportunity permits. Data will be collected to address whether continued exposure to oil or predation are impacting octopus populations. The status of octopus in Prince William Sound is unknown. Their biology is poorly understood. There is little doubt that octopus were affected by the *Exxon Valdez* oil spill. This study is to collect information on how to approach the restoration or management of this important subsistence resource.

Objectives for the project are to 1) estimate of the density of octopus in nearshore habitats and the variability of octopus density between years and among sites; 2) provide an indication of status of the octopus population as measured by the size and sex distribution of octopus, the frequency of injuries and the turnover rates in different habitats, and the characteristics of occupied habitats and dens in Prince William Sound; 3) collect incidental data on chiton during octopus surveys; and 4) convey results of the project to subsistence users on an annual basis.

D. Completion date

The project will be completed when the final report is finished in April 1997.

COMMUNITY INVOLVEMENT

This proposal is a direct result of public input received via the EVOS Trustee Research Priorities workshop (April 1994) and conversations about subsistence use of the nearshore with Jody Seitz, Martha Vlasoff, and Tatitlek residents. The project is designed to solicit and support collaboration with subsistence users and area fisherman to sample sites with a historical harvest of octopus. We will provide opportunity for subsistence users to contribute to decisions about study design and sampling location. We welcome further public input, and anticipate opportunities to talk with members of the public at EVOS-sponsored workshops and community visits in Tatitlek and Chenega Bay.

PROJECT DESIGN

A. Objectives

1. Regularly survey intertidal beaches historically harvested for subsistence use to determine the density of octopus and chiton above the water line at minus tides, and estimate injury and turnover rates;

2. At selected subtidal survey sites, use SCUBA to search subtidal areas judged to be good microhabitat. In these areas, record 1) the local density of octopus, 2) the age and sex distribution of octopus; 3) the number of brooding female octopus, 4) the species composition of feeding litter, and 5) injury and turnover rates;

3. Identify features of substrate, flora, and fauna typical of areas where octopus are captured. As far as possible using existing data, estimate the extent and location of good nearshore octopus habitat in Prince William Sound;

4. Report survey results to subsistence users in Tatitlek and Chenega Bay on an annual basis.

B. Methods

Each of the possible methods for surveying octopus has limitations. For this reasons, a survey combining several techniques seems likely to yield the most complete information. We will utilize the results from the initial field surveys (FY 95) to select the most suitable sampling techniques. The largest changes anticipated from last year are that the results of the first field season will be used to select one or two promising survey sites. Focusing on fewer sites will then allow repeated sampling at a site. Repeated sampling and the use of tags to mark octopus will allow the estimation of turnover rates. Regular surveys of beaches utilized by octopus will be conducted during minus tides, similar to the design for FY 95.

Analysis of the SCUBA data will provide estimates of octopus densities in the microhabitats searched. We will use existing sources of underwater habitat data (e.g. ADF&G herring spawn deposition dives, Coastal habitat project) to indicate the regional abundance of habitat features associated with the presence of octopus.

1. Intertidal surveys - Techniques used to survey intertidal dens in FY 95 will be used again in FY 96. Local knowledge of subsistence harvesters is used to identify historically harvested sites and candidate sites judged likely to be good octopus habitat. At each site, we will look for octopus and chiton during beach walks conducted during minus tides. Areas will be searched by looking in likely octopus dens (e.g. crannies along the ocean side of big boulders) and searching for octopus sign (e.g. feeding litter).

2. SCUBA surveys - Nearshore shallow subtidal areas at each site will be surveyed using SCUBA dives. Pairs of divers will search using method similar to those described for intertidal surveys. We will record the extent and defining characteristics of each patch of habitat searched intensively. If long-line

pots sampling proved useful in FY 95, we will employ this technique again this year. When the bottom is not too deep, divers will survey the pot lines to record the habitat type in which each pot landed. Lair-pots will not be deployed if, in the opinion of the fishermen, dive survey sites are not suitable for pot fishing (e.g. too rocky).

For each octopus found on both intertidal and SCUBA surveys, we will record location, species, size, sex, den characteristics, whether eggs are present, and whether the octopus has been tagged. Octopus will be tagged the first time that they are captured, except that octopus brooding eggs will not be captured or handled. If feeding litter is present, we will sample this to identify prey. The substrate and characteristics of the den location will be recorded. While surveys are designed to find octopus, we will also collect data on the abundance of chiton, particularly when surveying intertidal habitats. For each chiton located, we will record location, species, size and substrate type.

Discussion of survey techniques: Three methods were considered for use in this survey. Lair pots were initially considered as a means of surveying using trap-grid methodologies. However, in Alaska, SCUBA sampling modeled after methods generally used for behavior observation and hand capture of octopus in the subtidal may be more effective. Finally, at minus tides, beach surveys were considered as an indication of the availability of octopus to intertidal harvesters, a technique used for subsistence harvest. Octopus are cryptic and mobile marine predators, and as such are difficult to survey accurately. Each of these three techniques has advantages and shortcomings.

Trapping grids are a common method of surveying small cryptic animals. Traps are usually baited to attract the animal, and the survey's reliability depends on the trap results providing an unbiased sample of the population (Seber 1982). As described above, the octopus' need for shelter supports a fishery using unbaited lair pots. A survey based on lair-pots is particularly attractive in this study because there is some evidence that artificial den placement may also provide a means to locally enhance octopus density under certain circumstances (see above). However, experiments with pot fisheries for octopus in Alaska have revealed that per-pot capture rates can be exceedingly low (Paust 1988), and that pot success is extremely variable depending upon the age of the octopus (Hartwick 1983), the distribution of food, and the availability of natural dens (Paust 1988). For these reasons, a pot-based survey of nearshore octopus may not be the best technique available.

SCUBA survey methods include fixed-width transect survey and area-search survey. Transect surveys provide greater statistical validity, precise estimates of the area surveyed and a careful, regulated sampling of the environment. While they are successful in enumerating abundant, stationary, and visible organisms (e.g. herring spawn, sea cucumbers) transect surveys are less successful when animals are scarce, mobile and cryptic. The linear miles of transect surveys necessary to locate and count reasonable numbers of octopus in Prince William Sound would likely be unmanageably large.

Area-search surveys focus intensively on the best microhabitats to find the target organism. As only prime microhabitats are searched, a greater area can be surveyed and the chances of locating organisms that occur at low densities are increased. Such surveys are non-random with respect to habitat type. Their design prevents precise calculations of the area surveyed and counts are not provided for sub-

optimal habitats. However, area-search surveys are ideal for determining the peak local abundance of an animal.

Area-search SCUBA surveys may sample octopus at about the rate of lair-pot lines with less than 100 pots. SCUBA surveys on Titlow beach (Puget Sound) involving a thorough search of the study area by multiple divers (research dive classes) yielded on average less than eight octopus found per survey (unpublished data in Kyte 1994). Of 96 octopus tagged and released in the same study, only 11.5% were recaptured. In another study (Kyte 1979), divers on the Edmunds artificial reef (Puget Sound) located 50 individuals over 75 dives (<1 per survey). In both cases, a given individual may have been repeatedly captured. These results may be compared to lair-pot capture rates. At pot occupancy rates of 12-18% reported for Alaska (Paust 1988), from 50-66 lair-pots would be required to catch the same number of octopus per site as were found by divers in Kyte 1994. No comparison of these techniques at the same time, location and depth has been made however.

Surveying at minus-tides above the water line may be modeled after either transect or area-search methods. Foot surveys follow the methods of traditional subsistence harvest and hence reveal that portion of the population available for subsistence use by this method. While these areas might also be sampled at high tides during the dive surveys, this would not indicate to what extent the octopus remain in these areas as the tides retreat.

Lair-pot trapping grid, SCUBA surveys using area searches, and intertidal foot surveys were all incorporated into the sampling design for the first field season, providing both a comparison of methods, and a broad sampling base should some methods be unsuitable. Some of these techniques may be discarded in FY 96 if they prove unsuitable. In the second field season, repeated visits are planned to each study site. The number and location of sites will be determined by the results of the FY 95 field work. However, repeated visits allow the use of tagging to estimate turnover rates.

Octopus can be marked either by injecting a dye under the skin or by attaching a small tag through the web between the arms. In either case, the marks are expected to last about 30 to 90 days. We will use tags rather than dye-marking. Tags will be marked or positioned to differentiate octopus from different capture sights. If possible, tags will be unique to identify individuals. Tagging studies of octopus have been very successful in Japanese waters where a commercial fishery for octopus is available to assist with tag recovery. Tagging studies have also been successful in indicating turnover rates when repeated site visits can be made.

We will recover tags by re-visiting sites anywhere from a few days to three months after tagging. In addition, although few recoveries are expected, we will encourage area fishermen and subsistence harvesters to watch for and return tags on animals they harvest.

3. Octopus habitat - For each octopus located on dive and intertidal surveys, a description of the habitat will be recorded including substrate type, slope, nearby vegetation or prominent invertebrate patches (e.g. mussel beds), and depth. The dive surveys will result only in an estimate of octopus density in areas judged *a priori* to be good habitat, as only these areas are to be searched intensively. *A*

priori definitions of good habitat will be developed from results of the first survey, expert consultation and descriptions available in the literature. These *a priori* indicators and characteristics of areas where octopus were located will be used to develop a description of the habitat sampled during dives. If available, existing data will then be used to estimate the regional abundance of this habitat.

To be suitable, data on habitat distribution must provide information on substrate and other bottom characteristics, be of similar scale to dive surveys, contain descriptors relevant to octopus distribution, be collected in an unbiased manner, and already be computerized. We are currently looking for existing data that meets these criteria. Candidates include data from ADF&G herring spawn deposition dives, the Coastal habitat project and from shoreline sensitivity indices. Analysis will also include reference to sea otter densities (J. Bodkin, NBS, has provided preliminary aerial survey data).

4. Community visits at the end of FY 95 and FY 96 will be used to report results to Chenega Bay and Tatitlek. Community visits and the involvement of subsistence harvesters are an important part of this project, so that reports to these communities can be accomplished with little additional cost.

C. Contracts and other Agency Assistance

Funds are allocated for charter of a vessel to support survey dives, beach access and possibly pot surveys. This vessel will likely be a privately-owned fishing or research vessel from a community in the EVOS-impacted area. A smaller vessel may also be needed for a short period of time to conduct preliminary beach surveys. A contract to conduct monthly low-tide beach surveys at historical harvest sites is also needed. It is anticipated that a subsistence harvester from a community located near each of the survey sites would contract for this work. Vessel and survey contracts will be awarded to the most suitable bidders responding to advertisement.

Equipment rental and services may also be needed to support short term use of small equipment in the field. In particular, we anticipate renting dive equipment and a field computer, as well as contracting for diver training and equipment repair and maintenance. Rental of dive equipment will likely be through R. Trani, Cordova Water Sports, who is providing negotiated rates in support of this project and is the only provider of such equipment in Cordova. Contracts will be awarded as needed to local businesses or individuals who can provide the necessary equipment or service at a reasonable rate.

Expertise of R. Highsmith (UAF) will be administered via contract between UAF and the Science Center. Dr. Highsmith will provide direction and consultation based on his experience with nearshore invertebrate communities. The contract budgeted for Dr. Highsmith is for this consultation and to assist with data interpretation on completion of the survey and related analyses. Travel funds are budget for travel between Cordova and Fairbanks.

D. Location

Prince William Sound.

SCHEDULE

A. Measurable Project Tasks for FY 96

Start up to six weeks:	Advertise and award contract for regular surveys of intertidal harvest sites, and vessel charters.
At three months:	Train contractor for intertidal surveys in data collection standards, begin monthly intertidal surveys at minus tides. Report results of FY 95 to subsistence users in Tatitlek and Chenega Bay. Conduct first field cruise including SCUBA and intertidal survey. Tag all octopus captured.
At six months:	Conduct second field cruise including SCUBA and intertidal survey. Recover tagged octopus and tag octopus captured for the first time.
At nine months:	Conduct third field cruise including SCUBA and intertidal survey. Recover tagged octopus and tag octopus captured for the first time.
At twelve months:	Conduct last field cruise including SCUBA and intertidal survey. Recover tagged octopus.

Dates for SCUBA surveys would be scheduled depending on start-up date, dates of minus tides and weather. If project start-up was in October as currently planned, surveys would likely be scheduled for December or January, April, July, and August or September. Coordinating SCUBA surveys with minus tides allows intertidal surveys to be conducted at the same time.
Conduct SCUBA survey 3.

B. Project Milestones and Endpoints

FY 95:	Design surveys; conduct initial survey at several sites across Prince William Sound. Identify most suitable sites for continued work in FY 96 and report on size and sex distributions of octopus, descriptions of typical den sites, and typical prey, difference among sites surveyed in 1995. Compare sampling techniques.
FY 96:	Conduct repeated surveys at selected sites; conduct tag-and-release studies; monitor harvest sites near Tatitlek and Chenega Bay through monthly intertidal surveys; assess variability in octopus density between sites and between the two years. Make community visits to Tatitlek and Chenega Bay to discuss results of first year.
FY 97:	Complete analyses; present data on octopus turnover rates in typical habitat; and assess evidence for and against the hypotheses that octopus are impacted by continuing exposure to oil or by high levels of predation. Write final report, and make results of project available to residents of Tatitlek and Chenega Bay through community visits or educational video.

C. Project Reports

By April 15th of each year, an annual report will be submitted on the milestones reached in the previous funding year. The FY 95 report will discuss initial survey results (including size and sex distributions of octopus, descriptions of typical den sites, and typical prey), difference among sites surveyed in 1995, and will compare techniques used. The FY 95 report will also identify the most promising sites for the field work in 1996. The FY 96 report will discuss the variability in octopus density between sites and between the two years; present data on octopus turnover rates in typical habitat; and assess evidence for and against the hypotheses that octopus are impacted by continuing exposure to oil or by high levels of predation. The FY 97 report will present the analysis of long-term behavioral changes and an analysis of dietary overlap based on behavioral data. The FY 98 report will provide the analyses of prey availability and estimates of predation rates on killer whales.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project, based at the Science Center will make every effort to share logistics, personnel and study sites with other restoration research, particularly projects with a base in Cordova (e.g. SEA research).

Air and boat transportation necessary to get researchers to remote locations in Prince William Sound will be shared with other restoration projects having similar needs. Cost sharing for transportation to and from field sites will likely occur with SEA projects and possibly with subsistence community outreach projects and has already been accounted for in the proposed budget.

Several of the analyses proposed in this project will rely on data collected under the restoration effort, including habitat data from ADF&G herring spawn deposition dives, the Coastal habitat project and from shoreline sensitivity indices. Analysis will also include use of sea otter density data (J. Bodkin, NBS).

ENVIRONMENTAL COMPLIANCE

The FY 96 portion of this project is expected to qualify for a NEPA categorical exclusion. A categorical exclusion has been obtained through the USFS for field work in FY 95.

Exxon Valdez Trustee Council project 96009-D: Survey of octopuses in intertidal habitats
Changes following 24 October 1995 review.
Please change the following in the Detailed Project Description (submitted 24 April 1995):

p 5, under Objective 2:
Change 'the age and sex distribution' to 'the size and sex distribution'.
Delete part 3 'the number of brooding female octopus'; renumber subsequent parts.

p 8, replace section 3. Octopus habitat with the following paragraphs:

3. Octopus habitat - Results from the 1995 surveys suggest that areas with greatest numbers of octopus (a) include a boulder field, (b) are adjacent to Zostera beds and Laminarian kelps, (c) have shallow slope. Of these three, boulder fields are suspected to be the most important to octopus and slope the least. Habitats can therefore be ranked from poor to most suitable based on the presence of flat slope, vegetation and boulders. We designate four habitat patch types, in predicted order of increasing suitability to octopus, according to the presence of: i) none of a, b, or c; ii) a, but not b or c; iii) a and b, but not c; and iv) a, b and c together.

The proposed sampling design will allow the importance of these three habitat characteristics to be determined. Patches of approximately equal area will be designated. Patches will be restricted to intertidal areas (upper fucus to minus 3.9 ft), as densities are expected to be higher in the intertidal than the subtidal (see below). At a single site, patches of each type will be located and the set of four surveyed. Sampling will be done at each of four to six sites during the low tide series June 30 to July 4. Differences in the mean for each patch type across sites will indicate the relative importance of boulders, adjacent vegetation, and slope.

Results from the 1995 survey also suggest that octopus densities are higher in intertidal areas than in nearshore-subtidal; and that densities are higher in areas with dense vegetation cover. To examine these predictions SCUBA surveys will be conducted adjacent to intertidal sites (see above). Surveys will be restricted to -5 to -30 feet to limit the effect of depth on octopus densities; and will be stratified by vegetative cover (two categories: greater than 75% kelps, 25% or less vegetative cover). Surveys will be conducted areas with boulders and shallow slopes, to the greatest extent possible. We will also survey vegetated and unvegetated subtidal patches in this manner at the two sites chosen for repeated surveys (see below). This will allow us to compare intertidal and subtidal densities and the effect of cover.

Turnover rates will be estimated within habitats by tagging and releasing all octopus encountered (see above). Repeated surveys of the same site at intervals of one to three days within a tide cycle and intervals of one to six months across cycles will allow us to calculate rates of loss (movement or predation) and settlement (new arrivals). We will tag all octopus encountered at all sites. Repeated surveys will be conducted at two sites. In each 6-day period when low tides are below -2.0 feet, each of two sites will be visited for three days. Sampling will be conducted 4 times during the year (probably early May, late May, late July and early December) when low tide series are suitable.

p 10, Replace section Measurable Project Tasks with:

First quarter:	Hire personnel, arrange insurance or dive contracts, advertise and award contract vessel charters, initial site visits to new sites; finish report from FY95 surveys.
Second quarter:	Report results of FY95 to subsistence users in Tatitlek and Chenega Bay. Begin field work including tag-recapture intertidal surveys at minus tides and SCUBA sampling.
Third quarter:	Continue tag-and-recapture and SCUBA sampling monthly. Conduct habitat sampling at multiple sites at the end of June.
Fourth quarter:	Final recapture of tagged octopus and last SCUBA survey. Begin data analysis and report writing.

p 11, under Project Reports
Delete 2nd paragraph.

:I

COMPREHENSIVE KILLER WHALE INVESTIGATION IN PRINCE WILLIAM SOUND, ALASKA (Submitted under BAA 52ABNF500082)

Project Number: 96012A

Restoration Category: Monitoring, Research

Proposer: North Gulf Oceanic Society

Duration: 3 years

Cost FY 96: 167.5

Cost FY 97: 151.0

Cost FY 98: 85.0

Geographic Area: Prince William Sound, Alaska

Injured Resource/Service: Killer Whales, Harbor Seals

ABSTRACT

This project continues the monitoring of the damaged AB pod and other Prince William Sound killer whales that has occurred on a yearly basis since 1984. It develops a GIS database on killer whales that when coupled with genetic and acoustic data will help evaluate recovery, recognize changes in behavior and estimate killer whale impact on harbor seals.

INTRODUCTION

This project is a continuation of the comprehensive killer whale investigation initiated in 1995 in Prince William Sound. Killer whales were monitored under EVOS Trustee Council funding in 1989, 1990, and 1991 (damage assessment) and in 1993 (restoration monitoring) will be monitored in 1995 as part of the comprehensive killer whale study.

A total of 14 whales were lost from resident AB pod in the two years following the Exxon Valdez oil spill and there was no recruitment into the pod during those years. On March 31, 1989 AB pod was observed in oil sheens and six pod members were missing. Since that time the social structure within the AB pod has shown signs of deterioration. Maternal groups have traveled independently, and pod members have not consistently traveled with closest relatives. Although 4 calves were recruited during the period 1992-1994, there were 5 probable mortalities in 1994 (to be

confirmed in 1995 monitoring). The rate of mortality observed in this pod after the oil spill far exceeds that recorded for other resident pods observed in Prince William Sound over the past 11 years or for 19 pods in British Columbia over the past 20 years.

Nine whales from the transient AT1 group have not been observed since 1989. However transient killer whale social structure is not fully understood and we cannot be completely certain that these whales are dead, although we suspect them to be (to be examined statistically in FY 95). In FY95 a comprehensive monitoring and reporting will occur, in following years (FY96-FY98) a reduced cost yearly monitoring is proposed with a comprehensive report in FY98. Recommendations for further monitoring will be considered. A catalogue of individual killer whales will be produced in FY 97.

Additionally, in FY95 as part of the comprehensive killer whale investigation (95012), eleven years of systematic data collected under public and private funding are being placed in a specially designed GIS system at the Prince William Sound Science Center. This data base will allow examination of feeding habits and other behaviors of killer whales before and after the Exxon Valdez Oil Spill and relate them to geographic area. One important product of this project will be to assess the impact of killer whale predation on non-recovering harbor seals in Prince William Sound. FY96 funding will permit the completion of the data input and its continued analysis. Continued analysis of long term behavioral changes and predation patterns will occur in FY97 and FY98. The products of this study will be consolidated with models developed for harbor seals (96064).

Additional observation and collection of killer whale prey remains will occur in FY95, FY96, with a reduced effort in FY97. Results will be incorporated into the GIS database and included in the final report (FY98). Biopsy tissue sampling for genetic analysis and lipid, fatty acid and isotope analyais will be conducted concurrently.

Two forms of killer whale, resident and transient have been described in the eastern North Pacific. Observations indicate that only the transient form consumes marine mammals. It is important that this distinction between residents and transients in Prince William Sound is verified in order to assess the impact of killer whale predation on harbor seals. Genetic analysis that will clarify segregation of killer whale types will be concluded in FY96.

There is very limited sighting information for killer whales during the November thru March period. With the assistance of the village of Chenega, a remote hydrophone in Montague Strait will be monitored on a year round basis. This will provide comparative data on the presence, identity, and duration of stay of killer whales in southwestern Prince William Sound at all times of year.

NEED FOR THE PROJECT

A. Statement of Problem

The AB pod of killer whales was injured by the EVOS. Although it had shown signs of recovery from 1991 to 1993, that recovery is now in doubt. The AT1 group of transient killer whales also appears to have declined since 1989. This project will monitor the recovery/non-recovery of AB pod and investigate possible cause recent changes within the pod. In addition, the long term significance of the apparent reduction in the AT1 transient group will be assessed.

Predation by killer whales may be a significant factor in the non-recovery of harbor seals, another damaged resource. Harbor seals have continued to decline since 1989 in Prince William Sound (16-20% reduction from 1989-1994). The analysis of historical data, continued observations and sampling of killer whale prey items, biopsy sampling and genetic analysis, and acoustic studies will assess the impact of killer whale predation on harbor seals.

B. Rationale

Yearly killer whale population monitoring will determine whether recovery of AB pod has occurred and will determine the status of the AT1 transient group. The actual status of AB pod after 1994 is unclear (whether recovering or non-recovering) and will only be clarified by continued monitoring. A low level annual monitoring program is proposed. All pods/whales are not observed in every year, annual monitoring will prevent extensive data gaps and allow certain determination of recruitment mortalities in a much shorter time frame. Additionally, an annual eleven year killer whale identification database now exists. Continuation of this approach will provide consistency in analysis and interpretation. Because killer whales are a long-lived species with low reproductive and mortality rates, this monitoring must be long term to be meaningful.

Killer whale predation is a possible contributing cause of the non-recovery of the spill damaged population of harbor seals. The proposed analytical approach will directly assess this possibility using historical data as well as continued observations of killer whale behavior and feeding habits. Determining the proportion of the killer whale diet that consists of harbor seals, the number of killer whales that eat harbor seals, and the whales residency in the Sound will be important components of this assessment and address restoration of harbor seals.

C. Summary of Major Hypotheses and Objectives

The study will address the following hypotheses:

Is AB pod continuing to recover from the Exxon Valdez Oil spill? Are restoration objectives reasonable?

Is there sufficient evidence to indicate that the AT1 whales missing since 1989 are likely to be dead?

What is the rate of predation by killer whales on harbor seals and has it changed since the EVOS?

Are transient killer whales (such as the AT1 group) and resident killer whales (such as AB pod) segregated and do they have separate diets. How does this impact harbor seals?

Do killer whales use southwest Prince William Sound in winter and if so which pods and to what extent? How does this impact harbor seals?

Is predation by killer whales sufficient to prevent recovery of the damaged harbor seal population?

D. Completion Date

The photographic monitoring,input of historic data, analysis of killer whale impact on harbor seals, biopsy sampling and analyses and acoustic monitoring will begin in FY95 and continue through FY97. The final report for all aspects of the project will be prepared in FY98. After FY98, continued monitoring of AB pod and the AT1 group may be recommended if restoration is not evident.

COMMUNITY INVOLVEMENT

There is great public concern and interest for killer whales in Prince William Sound. We will involve tourboat and recreational operators and residents by exchanging sighting information on a daily basis and providing a catalogue of individual whales to enhance enjoyment of whale observation. With our supervision, the residents of Chenega and students at the Chenega school will become directly involved in the killer whale project by monitoring and maintaining a remote hydrophone system and participating in the data analysis. Chenega residents will be contracted to maintain the system.

PROJECT DESIGN

A. Objectives

1. Determine the recovery status of the AB pod of resident killer whales. Examine the demographics of this pod and other resident killer whale pods. Review and possibly redefine measurements used to determine recovery status of killer whales.

2. Assess the possibility that permanent changes in the AT1 transient group of killer whales (ie. emigration or death) have occurred since 1989.

3. Estimate the extent of segregation of killer whale populations (resident and transient) in Prince William Sound based on genetic analysis and behavioral data.

4. Provide blubber samples for lipid/fatty acid and isotope analysis (to National Marine Mammal Laboratory in FY95)

5. Complete the entry of historical data relative to feeding, habitat use, behavior and distribution of killer whales into a computerized GIS format; and enter each additional years data as it becomes available from field work.

6. Examine spatial and temporal aspects of killer whale predation (particularly on harbor seals)in Prince William Sound.

7. Numerically estimate the impact of killer whale predation on harbor seals in light of the non-recovery of harbor seals since the EVOS.

8. Assess the year round residency of killer whales (by pod) using a remote hydrophone system monitored at Chenega Community School.

9. Update and publish a catalogue of individual killer whales used by researchers, tour boat operators, recreational boaters and others to identify whales.

B. Methods

Killer Whale Monitoring

The goal of this aspect of the study is the photoidentification of each individual in each pod/group, that regularly uses the Sound, particularly AB pod and the

AT1 group. Currently killer whales are considered recovered when AB pod is restored to 36 individuals. Because this may be a narrow and unrealistic restoration objective, the FY95 report (currently funded) will present alternative definitions of recovery which would change the methods for determining restoration status of killer whales. Knowledg of the demographics of all regularly sighted pods and groups may be necessary to meet new recovery definitions.

Thus, it is important that researchers maximize the time actually spent with killer whales (particularly AB pod) to insure thorough identification of all individuals. Methods proposed to obtain photographic data necessary to meet monitoring objectives will be similar to those used by the North Gulf Oceanic Society in Prince William Sound for the past eleven consecutive years. Searches for whales will not be made on random transects, but based on current and historical sighting information. In addition whales will be located by listening for killer whale calls with a directional hydrophone (calls can be heard up to 10 miles away), or by responding to VHF radio calls from other vessels reporting sightings of whales. We have developed network of cooperating vessel owners that regularly report whale sightings. In addition requests for recent killer whale sightings will be made routinely on hailing Channel 16 VHF.

A vessel log and chart of the vessel track will kept for each day the research vessels operate. The elapsed time and distance traveled will be recorded and vessel track plotted. Record will be made of the time and location of all whale sightings and the weather and sea state noted at regular intervals (see attached data sheets).

Specifics of each encounter with killer whales will be recorded. Data recorded will include date, time, duration, and location of the encounter. Rolls of film exposed and the estimated number of whales photographed will also be recorded. A chart of the whales' trackline during the encounter will be completed and the distance traveled by the vessel with the whales will be calculated. General behavior of the whales (i.e. feeding, resting, traveling, socializing, milling) will be recorded by time and location.

Photographs for individual identification will be taken of the port side of each whale showing details of the dorsal fin and white saddle patch. Photographs will be taken at no less than 1/1000 sec using Ilford HP5, a high speed black and white film, exposed at 1600 ASA. A Nikon 8008 autofocus camera with internal motor drive and a 300 mm f4.5 autofocus lens was used. When whales are encountered, researchers will systematically move from one subgroup (or individual) to the next keeping track of the whales photographed. If possible, individual whales will be photographed several times during each encounter to insure an adequate identification photograph. Whales will be followed until all whales are photographed or until weather and/or darkness makes photography impractical.

accounting of changes in AB pod and the calculation of recruitment rates and mortality rates for AB pod and the other major resident pods, providing that all pods are completely photographed. Changes within AB pod will be examined with consideration for the age and sex structure of the pod and maternal groups within the pod. Changes in the demographics of the ATl transient group will be assessed. Pertinent statistical assessments will be made every third year. Frame by frame input of identification data from exposed film into VAX computer system will occur annually. Copies of identification data as well as field data sheets will be made available to the EVOS Trustee Council annually.

Killer Whale Predation

A primary task in this study of killer whale predation is the entry of historical data into the GIS system at the Prince William Sound Science Center. This requires the design of a database (to be completed in FY95) and access to data collected by NGOS and NMFS. The available data has not been completely inventoried. However, it is estimated that NGOS records from 1983 to 1994 contain about 560 encounters recorded (360 post spill) encompassing 1700-3500 hours of whale observation during 9000-18,000 hours of field effort (including data collected during NMFS/NGOS damage assessment from 1989-1991). NGOS has agreed to provide access to their data under a 1995 amendment to an existing Memorandum of Understanding between NGOS and the PWSSC. The available data, database design and the initial data entry efforts are described in detail in the response to NOAA's RFP for the FY95 portion of the work.

The results of a literature review completed during FY95 will be used to determine the most useful method of calculating search effort. Prior to the literature review, it is premature to detail the methods of reconstructing search effort. Currently we intend to model this analysis after the grid-based geographic analysis of killer whale ecology of Heimlich-Boran (1988 Can.J. Zool. 66:565), as this study was conducted in a similar manner on the same species. A geographic grid can be laid over the killer whale study area using Arc/Info GENERATE or GRID routines. Once this grid is created, the amount of time and distance traveled by each research vessel in each grid cell can be tabulated. Killer whale encounters or time spent with the whales can be tabulated in a similar manner. For each cell, it will then be possible to calculate a measure of sightings per unit effort. This method currently appears suitable, but we expect to refine these calculations based on the review of the literature. Search effort will be calculated on a least an annual basis for each year. Where appropriate, effort may be tabulated by season or month.

Analyses will be designed to address questions regarding long-term changes in whale behavior, and the relationship between such changes and the 1989 oil spill.

All photographic negatives will be examined under a Wild M5 stereomicroscope at 9.6 power. Identifiable individuals in each frame will be recorded. When identifications are not certain, they will not be included in the analysis. Unusual wounds or other injuries will be noted. Photographic negatives will be analyzed using a photographic database that spans eleven 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. (1994) in Marine Mammals and the Exxon Valdez (T.L. Loughlin editor).

A substantial photographic database was collected from 1992, 1993 and 1994 by NGOS with private money. These photographs have not been completely analyzed. As part of the FY95 project, these photographic negatives will also be examined frame by frame and the whale identities computerized. This data will be important in the overall assessment of population dynamics within pods and within the population. The monitoring program and comprehenive report in FY95 (detailed in the response to NOAA RFP) will lay the groundwork for the continuation of monitoring proposed for FY96-FY98.

The primary vessel used to secure identification photographs will be a 27' deisel inboard/outboard powered vessel that can sleep two individuals (Whale 2). With sleeping accommodations and large fuel capacity, the Whale 2 will return to camp or to Chenega Village (fuel storage) infrequently which greatly increases available time searching for or photographing whales. Although this vessel will primarily collect photoidentification data, it will collect feeding habit observations and samples and biopsy samples for the predation studies. The operator of this vessel, Eva Saulitis, has eight years experience in the Sound conducting photoidentification of killer whales and humpback whales and collecting food habit data. This vessel will operate a total of 50 days, from early July through late August. From historical data these dates are judged to be to be the most likely time to encounter AB pod as well as many of the other resident pods that use the Sound. Photographic data will also be collected from the 43' R.V. Lucky Star and its associated skiff (32 days in the field) when it does not interfere with the primary goal of this vessel of providing feeding habit observations and samples of prey remains and biopsy samples for predation studies. The R.V.Lucky Star will also deliver fuel to designated locations and provide other logistical support for the operation of the R.V. Whale2.

Annual reports (FY96,FY97) for the monitoring segment will include a summary of field effort, and summary of the pods and individuals encountered and a status report on AB pod and the AT1 group. Comprehensive reports made every third year (FY95,FY98) also will include a detailed

For example, it has been suggested that transient whales have become more difficult to locate following the oil spill. Measures of whale behavior and distribution will be examined by comparing sightings per unit effort and behavior frequencies in pre-and post-spill periods. This will be accomplished first by calculating sightings per unit effort for each year of the data base. Comparison between years in each time period (pre- and post-spill) will be sued to indicate whether any group of whales have become more difficult to locate within the study area and whether the change corresponds to the time of the spill. Similar calculations will indicate whether feeding or other behaviors have changed in frequency or moved in location over the years. For example, the grid-based analysis used for calculating search effort can be repeated on occurrences of each behavior category in each cell. As appropriate and allowed by sample sizes, these can be split by pod type, pod ID, or month and year of sampling. Parametric or non-parametric statistics will be used to evaluate the evidence for the hypothesized changes in behavior.

Previous analyses of this data as well as results from other studies indicate that resident and transient killer whales have minimal dietary overlap. An analysis of observations of transients feeding (E.L. Saulitis, 1993, M.S. thesis, University of Alaska,Fairbanks) found very little indication of fish in the transient diet. A comparable tabulation of observation time and feeding habits of resident whales has not been published from this data. We will tabulate the number, duration, and location of feeding behaviors for all records in the data base and examine the results for evidence of dietary overlap between the two types.

Hypotheses will be formulated and evaluated regarding possible causes for the patterns documented. This may involve use of data on the distribution of prey that is available from other research projects. Possible candidate data sets on prey availability include the SEA program data base, expected to include detailed data on the seasonal distribution of harbor seals from the population surveys or as reflected in the distribution of subsistence harvests; annual salmon or herring harvests by the fishing fleet; or other data as available. Prey distributions will be obtained by the most appropriate means from the candidate data set. The prey and predator distributions can then be overlaid in Arc/Info to examine hypotheses regarding the spatial associations of whales and their prey or of whales and other important features of their habitat (e.g. rubbing beaches, etc.).

A key aspect of this work will involve evaluation of the hypothesis that killer whale predation is impacting the recovery of harbor seals in Prince William Sound following the EVOS. The detail of this analysis may be limited by both the available data on killer whales and the available data on harbor seals. However, the killer whale

observational data will be used to estimate the number of harbor seals taken by killer whales. The results will be used as input to the harbor seal mortality model to ascertain whether killer whales are a limiting factor on the recovery of harbor seals.

Estimates of predation rates will be obtained by calculating the observed predation events per day of killer whale observation. To the extent the data will allow, factors influencing the predation rate (e.g. resident v. transient whales, group size, location, time of year) will be examined. Combined with the information on whale distributions available in the database, estimations will be made of the predation rate on harbor seals.

Behavioral observations, sampling of prey items, and biopsy sampling and processing in FY96 and FY97 will be conducted from The 43' R.V. Lucky Star and associated console skiff. Additionally, the R.V. Whale 2, the primary platform for the completion of the monitoring fieldwork, will make observations of whale behavior and sample prey remains. The R.V. Whale 2 is equipped to allow collection of biopsy samples which will be collected when it does not interfere with the completion of photographic monitoring of killer whales.

The R.V. Lucky Star can house 4 scientists and has work space and equipment sufficient for complete workup of samples taken by biopsy as well prey samples. Freezing facilities for storage of samples are available on both the R.V. Whale 2 and F.V.Lucky Star. Most biopsy sampling will actually occur from a 17' fiberglass skiff that will be launched from the R.V. Lucky Star. The highly maneuverable skiff is equipped with high sides and a raised deck, an operations console (hydraulic steering, remote speed and shift controls) and a 60hp outboard motor. The skiff has unobstructed visibility and is fast and maneuverable allowing for close approaches to whales with minimal disturbance and rapid retrieval of biopsy darts

The biopsy sampling for the genetic analysis (and potential chemical analysis) will be collected without handling or tranquilizing the whales. A small dart will be fired from a specially outfitted pneumatic rifle. The setup is similar to that used to deliver tranquilizing drugs to terrestrial mammals in wildlife research. A lightweight plastic dart (approx. 10 cm long by 1.2cm dia.) is fitted with a bevelled tubular sterile stainless steel tip that will take a small core of skin and blubber (approximately 1.8cm long and 0.5cm diameter). The sterilized dart will be fired from a range of 16-20m. The dart hits the animal in the upper back (in the area of the saddle patch), excises a small tissue sample and bounces off. The dart floats with the sample contained until retrieved. Identification photographs using data-back equipped cameras will be taken of all whales biopsied to insure accurate identification of the individual. The whales will be approached by researchers

in the manner currently authorized under permit No. 840 (held by the North Gulf Oceanic Society) for photoidentification and biopsy sampling of killer whales. The required report detailing sampling in 1994 was submitted to the National Marine Fisheries Service, Office of Protected Resources and the permit reauthorized for 1995.

NGOS has successfully biopsy sampled 25 individually identified killer whales in Prince William Sound under this permit in approximately 12 days of fieldwork (an average of about 2 samples per day). Allocated vessel time in FY96 should be more than adequate to obtain 40 or more samples, if required. Members of the NGOS field team have now biopsied more than 125 killer whales (most in British Columbia). Samples have been used for genetic, lipid/fatty acid/isotope, and contaminant analysis. Only a small piece of skin is required for genetic analysis, the remainder of the sample is potentially available for lipid/fatty acid and isotope analysis.

The field observation and sampling of prey remains as required for predation studies will occur concurrently with biopsy sampling from the R.V. Lucky Star. It will be conducted from the console skiff (described above) and independently from the R.V. Whale 2. It requires a fine mesh, extendable net for scooping prey remains from the water. Detection and recovery of fish scales or small bits marine mammals requires an experienced observer. Members of our research team pioneered the use of this technique and are competent in its use. Signs of killer whale predation are often subtle and transitory. Generally, fragments of blubber, hair, blood, oil, scales of fish and milling of the whales are the only evidence a predation event has occurred. When obtained, samples will be preserved by freezing (tissues) or in envelopes (fish scales, hair) for later identification.

Methods used to locate killer whales for predation and biopsy work will be similar to those outlined for photoidentification monitoring. However, it is anticipated that the R.V. Lucky Star will spend longer time periods with with particular groups of whales maximize biopsy sampling, behavioral observations, and collection of prey remains. In the case of marine mammal predation, extensive time must often be spent with the whales before a kill is observed.

The FY96 genetic study will focus on variable regions of the nuclear DNA, and will complement the mitochondrial DNA (mtDNA) analysis carried out in FY95. Because mtDNA is inherited maternally, the first year of the study will have estimated the extent to which females move between the resident and transient populations. The nuclear DNA analysis will provide more precise information on gene flow between the two populations. For example, it will make it possible to estimate the frequency with which intermatings occur, even in the absence of female emigration. Based on the photoidentification studies that have been carried out in British Columbia and Prince William Sound to date, it

appears that emigration occurs very rarely if at all, but these studies have not ruled out the possibility of intermatings.

The type of nuclear marker that will be used in FY96 will depend on the results of the analysis in FY95. Two approaches are most likely: microsatellite typing and exon-primed intron crossing (EPIC) analysis. Microsatellite markers are useful for assessing levels of relatedness ranging from parent-offspring to sub-populations. The individual who will carry out this part of the study, Lance Barrett-Lennard, is currently using microsatellite typing to investigate the genetic structure of resident killer whale communities and to compare resident and transient populations in British Columbia. EPIC analysis may be used if the mtDNA study and preliminary microsatellite analysis indicates a high degree of separation between the two populations.

To asess year round residency of killer whales, a remote hydrophone will be attached to the sea floor near Sleepy Bay, Latouche Island. An anchored and encased cable will run from the transmitter on shore to the hydrophone at a depth of about 15 meters. The transmitter will be enclosed in a waterproof case and the antenna placed in an adjacent tree. It will be powered by deep cycle batteries stored in waterproof containers. A solar panel will charge batteries in summer months, in winter, residents of Chenega Village will be contracted to recharge and replace batteries.

During summer months the hydrophone will be monitored from the R.V. Whale 2 via broad band receiver to assist in locating whales. During winter months it will be monitored at the Chenega Community School under supervision of principal/teacher Mr. Don Kinsey. The receiver will be connected to cassette recorder so that calls can be recorded. The receiver will be monitored on a regular scheduled basis. Analysis of the calls will be made using specially developed program (developed by Dr. John Ford, Vancouver Public Aquarium) using Macintosh Canary software. Some analysis will take place in the school, and will be directed by Eva Saulitis. Identities of the pods can be determined by calls. The frequency of occurrence of each pod by month will be recorded. Because pod sizes will be determined by photographic monitoring in summer months, estimates of numbers of whales using the area by month will be developed.

All equipment needed to complete the contracted field research will be provided by the North Gulf Oceanic Society, including binoculars, nets, directional hydrophones, photographic equipment, biopsy equipment, and on board laboratory supplies and equipment. New equipment needed for FY96 work will be purchased using matching funds (see budget) Additional supplies and minor equipment will be purchased as necessary. Apple Macintosh and IBM compatible computers owned by NGOS as well as the full array of

computers and the GIS system available at the PWSSC will be used in data analysis.

C. Contracts and Other Agency Assistance

The entire project will be completed under the auspices of the North Gulf Oceanic Society. Analysis of historic data for the killer whale predation segment of this work will be contracted to the Prince William Sound Science Center by the NGOS. The PWSSC has the GIS and computer systems and individuals with the expertise to successfully complete this task. The NGOS will contract residents of Chenega Village to monitor the remote hydrophone system during the October to May period. Contracts for vessel leases will be issued by the North Gulf Oceanic Society. We will provide samples or assist in the collection of samples for lipid/fatty acid analysis proposed by NMFS/NMML to the extent possible.

D. Location

Field work for this project will occur in Prince William Sound and immediately adjacent waters. Benefits will be realized by various user groups in the Sound, including local residents, tour boat operators, and recreational boaters concerned with the future of killer whales in Prince William Sound.

SCHEDULE

A. Measurable Project Tasks for FY96

Start-up to September 1:	Complete input of historical killer whale data and 1995 data into GIS system at PWSSC
Start-up to 3 months:	Complete design of sampling effort analysis
3 months to 6 months:	Design data inventory and analyses of long term behavioral changes
6 months to 9 months:	Begin data inventory and analyses of search effort
9 months to 11 months:	Complete search effort analyses and data inventory
Start-up to April 5:	Arrange logistics, prepare boats, equipment

April 9-20:	First cruise killer whale predation study emphasis
June 5-June 15:	Second cruise killer whale predation study emphasis, installation of remote hydrophone
July 11-August 30:	Killer whale monitoring emphasis field work
September 3-17:	Third cruise killer whale predation study emphasis
October 1- November 30:	Analysis of field data, genetic samples and historical data, assessment of hydrophone project
November 1-30:	Preparation of killer whale annual monitoring report
November 15-December 30:	Preparation of killer whale predation annual report

The R.V. Whale 2 will operate for 50 days in July and August (July 11 to August 30). The primary function of this vessel will be killer whale photoidentification monitoring. This time period is generally a period of high encounter rate with AB pod and other resident pods and will complement the schedule of the R.V. Lucky Star. In addition the R.V. Whale 2 will collect biopsy samples and feeding data opportunistically when it does not interfere with the monitoring segment of this project and monitor the remote hydrophone project.

The field schedule for the predation study is designed to obtain a fairly broad seasonal picture of killer whale predation. The early season fieldwork for the R.V. Lucky Star will be aimed at sampling transient killer whales. Resident whales generally are sighted more frequently later in the season. The remote hydrophone system will operate in FY96 and FY97 with analysis to be completed in FY 98.

B. Project Milestones and Endpoints

FY95: Conduct killer whale monitoring program and produce comprehensive report. Determine current recovery status of AB pod and review measurements used to determine this status. Initiation of field sampling/observation of prey and biopsy sampling of killer whales and completion of initial genetic analysis (mtDNA). Samples for lipid/fatty acid and isotope analysis provided to National Marine Mammal Laboratory. Design database for historical data; enter about half of existing data; inventory data that is computerized. Testing of remote hydrophone system. Annual

report for killer whale predation study.

FY96: Conduct reduced annual monitoring and produce annual report. Collect second season of field sampling/observation of prey data and biopsy samples of killer whales. Complete genetic analysis and summarize resident/transient separation. Complete data entry and inventory of historical data including FY 95 data, complete analysis of sightings per unit effort; design subsequent analyses; make suggestions for improvements in design of data collection. Install and operate (over the winter) the remote hydrophone system. Complete annual report for killer whale predation study.

FY97: Conduct reduced annual monitoring and produce annual report. Publish catalogue of individual killer whales. Final (reduced effort) field season for field sampling/observation of killer whale predation. Enter the FY96 data into GIS; complete analysis of long-term behavioral changes; make behavioral estimate of diet overlap between resident and transient killer whales; determine requirements of prey availability data and locate suitable databases. Operate remote hydrophone system and begin analysis of calls. Complete annual report for killer whale predation and acoustics studies.

FY98: Conduct killer whale monitoring program and submit a comprehensive report. Assess restoration status of AB pod, review definitions of recovery and assess changes in the AT1 transient group. Summarize all killer whale prey sampling/observational field data. Enter FY97 data into GIS system. Analyze prey and whale distribution data; estimate predation rate on harbor seals. In consultation with NMML or others, compare behavioral and chemical estimates of diet overlap between resident and transient whales. Analyze all killer whale calls collected from the remote hydrophone and assess year round killer whale residency. Write final report addressing all aspects of the project.

C. Project Reports

For the killer whale monitoring segment of this project, a draft annual report will be submitted by November 30, 1996, with the final report submitted after review by March 30, 1997. Another annual report will be submitted by November 30, 1997 and final report submitted March 30, 1998. A comprehensive report on the monitoring will be made in 1995 (under current year funding) with the next comprehensive report scheduled for December 31, 1998 (draft) and final version submitted by April 15, 1999. The annual reports will summarize effort and detail changes in pod

composition for that particular year. The comprehensive reports on monitoring will compare effort and sighting rates for each year and detail demographics within the pods and groups. It will assess the significance of changes and long term trends in the population particularly changes in AB pod. Comprehensive reports will specifically address changes in regard restoration goals and the likelihood of meeting those goals.

Annual reports for the killer whale predation studies will be submitted by December 31, 1996 and 1997 (draft), and final annual reports by April 1, 1997 and 1998. The project final report will be submitted November 30, 1998 and the final version completed by March 31, 1999. The FY95 (current year) report will summarize field effort, predation observations, and biopsy collection; report on initial genetic analysis; and discuss database design and provide a preliminary data inventory. The FY96 report will summarize field effort, summarize predation observations; report on the continued genetic analysis; describe the initial results of the remote hydrophone project, provide a completed inventory of historic data and present an analysis of search per unit effort. The FY97 report will summarize the limited field effort, summarize predation observations and final biopsy collection; summarize initial analysis of remote hydrophone data; present the analysis of long-term behavioral changes and analysis of dietary overlap based on behavioral data. The FY98 report will provide the final summary and interpretation data from genetic analysis and the remote hydrophone project; detail and interpret the results of field efforts; and provide analyses of prey availability and estimates of predation rates for killer whales.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The monitoring of killer whales and analysis of historic and current data on killer whale behavior is part of an integrated program to investigate killer whale recovery and the impact of killer whale predation on harbor seals. It will be integrated with the harbor seal trophic studies (project 96064, Kathy Frost, project leader). In addition, this project will offer tissue samples for use in the lipid/fatty acid and isotope analysis of killer whale tissues that is proposed separately by NMML/NMFS. Details of sample sharing remain to be worked out.

In 1996 this project will rely on approximately $10,000 in matching funds from foundations or other private sources. Additional monies may be avaialable following approval of this project. Matching monies will be sought in preparation of a killer whale catalogue (FY 97). The total cost of the catalogue is $20,000 of which $7000 is expected to be obtained elsewhere. The offset of expenses by matching funds in long term monitoring has subtantial future

with private funding sources, NGOS work with Trustee Council cooperation to maximize potential for matching funds in the future.

ENVIRONMENTAL COMPLIANCE

The North Gulf Oceanic Society has a federal permit to conduct both photoidentification studies and biopsy sampling of killer whales in Prince William Sound, Alaska. An environmental assessment was conducted by the National Marine Fisheries Service in issuing this permit. The NGOS also is finalizing a permit from the Chenega Native Corporation for placement of a remote hydrophone transmitter on their lands at the north end of Latouche Island.

Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators

Project Number:	96025
Restoration Category:	Research
Proposer:	National Biological Service/DOI
Lead Trustee Agency: Cooperating Agencies:	National Biological Service/DOI, ADFG, NOAA, USFWS
Project Duration:	4 years
Cost FY 96:	$1,728,200
Cost FY 97:	$1,669,400
Cost FY 98:	$1,669,400
Cost FY 99:	$ 450,000
Geographic Area:	Western Prince William Sound
Injured Resource/Service:	Sea otter, River otter, Harlequin duck, Pigeon guillemot, intertidal organisms, subtidal organisms

ABSTRACT

The Nearshore Vertebrate Predator Project (NVP) makes an integrated assessment of trophic, health, and demographic factors across a suite of apex predators injured by the spill to determine mechanisms constraining recovery and to improve our knowledge of the status of recovery. Primary hypotheses are: 1) recovery of nearshore resources injured by EVOS is limited by recruitment processes; 2) initial and/or residual oil in benthic habitats and in or on benthic prey organisms has had a limiting effect on the recovery of benthic foraging predators; and 3) EVOS induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators.

INTRODUCTION

Because of shorelines and coastal physiography, the nearshore ecosystem served as a repository for much of the oil spilled by the T/V *Exxon Valdez* (EVOS). Mortalities occurred across a suite of apex predators, as well as in benthic invertebrate populations, including mussels, clams, and crabs. The initial changes in composition and abundance of species which resulted from these acute mortalities and habitat disturbances likely continue to modify important structuring processes in the nearshore populations (i.e., competition, predation, and recruitment), thus constraining recovery. This is a 5-year project that received approval from the Trustees in March, 1995 and will begin data

collection in late summer, 1995. The project examines the status of recovery of four selected top vertebrate predators (sea otter, river otter, pigeon guillemot, and harlequin duck) in the nearshore environment of Prince William Sound and is designed to assess mechanisms constraining their recovery. Work to be undertaken in FY 95 includes primarily pilot efforts. These efforts will be used to establish final sample size and experimental design requirements for prey sampling (invertebrates), validate a number of techniques and establish up-to-date sea otter population data prior to full study implementation of the study in spring FY 96. However, the sea duck component of the study will be initiated in full because of its fall/winter data collection needs. There will be three full field seasons (FY 96, 97, 98) in the NVP Study with study closeout in FY 99.

NEED FOR THE PROJECT

A. Statement of Problem

The nearshore marine ecosystem of Prince William Sound (PWS) plays a critical role in the commercial, subsistence, and recreation economy of southcentral Alaska. Because of shorelines and coastal physiography, the nearshore ecosystem served as a repository for much of the oil spilled by the T/V *Exxon Valdez* (EVOS). As a result, many of the injured resources under study by the *Exxon Valdez* Trustees Council are components of the nearshore system. Thus, we propose the Nearshore Vertebrate Predator (NVP) study, which describes a research approach for assessing the biological and ecological significance of trophic issues and contaminants present in the environment. We focus on the status of system recovery and a suite of injured apex predators as indicators of environmental stress—the invertebrate feeding sea otter and harlequin duck, and fish feeding pigeon guillemot and river otter. The first three of these species have not recovered from EVOS, and the recovery of the fourth is unknown. NVP takes a multispecies, integrated approach to assess several potential key mechanisms constraining recovery of the nearshore system.

B. Rationale

Effective implementation of the EVOS Trustees Council's policy that "Restoration should contribute to a healthy, productive and biologically diverse ecosystem...", is complicated by the diversity and trophic interdependence of the numerous injured resources within the nearshore system. Beyond these ecological constraints, we are practically constrained in judging restoration by a lack of accurate and precise pre-spill population demographic data for many injured resources upon which to judge the progress of restoration. However, sufficient evidence exists to suggest that a wide variety of nearshore vertebrate predators and crucial subtidal and intertidal invertebrate prey are not recovered. The three factors most likely to be limiting recovery are intrinsic demographic constraints, continued hydrocarbon exposure, and food limitation. Concurrently, these data will provide information regarding the status of recovery.

Demography—Demography will be examined by comparing population densities and parameters affecting population growth rates between oiled and unoiled sites. The rate of recovery of nearshore vertebrate predators may be constrained by oil-related factors (continued toxicity of oil and food availability) as well as non-oil related processes. The latter include death and birth processes as

affected by factors such as intrinsic reproductive capacity and mortality due to adverse weather conditions. It may be, for example, that death and birth rates do not differ among injured and non-injured subpopulations of nearshore vertebrate predators, but that the rate of population increase is too slow to have allowed for complete recovery of the injured nearshore vertebrate predator populations., in the absence of continued effects of oil. In other words, the nearshore vertebrate predator populations may not be fully recovered, but may be recovering as quickly as possible under naturally-occurring conditions.

Continued Hydrocarbon Exposure—The question of continued exposure to oil will be assessed by comparing indicators of exposure to oil and individual health between oiled and unoiled sites. Today, hydrocarbon impacts may still exist. Between 8-16% of the 10.8 million gallons of crude oil spilled by the *Exxon Valdez* remains buried in marine sediments. Such oil is not subject to degradation by marine organisms and remains in a form that is toxic to many vertebrates. Moreover, microbial analyses suggest that oil in sediments along oiled shorelines is still several orders of magnitude more common than in unoiled sites, suggesting oil may still be available for biological transport from benthic invertebrates through the food chain. In fact, various bioindicator and health measures suggest that continued injury may be occurring among vertebrate predators.

Food Availability—Food limitation will be considered by examining population densities and size class structures of dominant prey species. Considerable dietary overlap and potential competition for food exists among the apex predators of the nearshore system. There is also strong evidence to suggest that population densities of many nearshore vertebrate predators are limited by food. For example, after initial immigration of sea otters into eastern PWS in 1979, the population increased rapidly over the next several years. Concurrent with this increase in otters was a rapid decline in many preferred prey items, including Dungeness crabs. Following prey reduction, sea otter populations declined and became relatively stable. Similar patterns have been observed at Amchitka and the Commander Islands. Evaluation of abundance and size distribution data for prey items may also be useful for providing additional indirect evidence for estimating recovery of some predator species. For example, it is well documented that sea otters prefer sea urchins as prey and that in the presence of strong predation by sea otters, both the abundance and average size of sea urchins is reduced. Other suggestions of food limitation exist for sea ducks.

C. Summary of Major Hypotheses and Objectives

For our test species, the document "Proceedings of the Workshop: Science for the Restoration Process" suggested that three factors had high potential as factors constraining recovery: 1) recovery of nearshore resources injured by EVOS is limited by recruitment processes; 2) initial and/or residual oil in benthic habitats and in or on benthic prey organisms has had a limiting effect on the recovery of benthic foraging predators; and 3) EVOS induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators.

Based on that consensus, we will ask "are vertebrate populations recovering, and if so, are they recovering as quickly as possible given potential rates of population increase?" by measuring population density and demographic factors (e.g., size and age distributions, birth rates, survival rates) at both oiled and unoiled sites to examine possible reasons for lack of recovery, and assess

progress toward recovery given demographic restraints. In conjunction with this "recovery monitoring" approach, we will also ask the question "is it oil?" or "is it food?" that limits recovery. This will be addressed through evaluation of demographic measures, health assessments, biomarkers of oil exposure, and availability of prey for the four nearshore vertebrate predators in oiled and unoiled areas of Prince William Sound.

D. Completion Date

The NVP Project objectives will be completed in FY 99.

COMMUNITY INVOLVEMENT

The project concept was developed as a result of the April 1994 "Science for the Restoration Process" workshop, a public forum. Continued discussion of the project occurred through the 1995 Work Plan and the initial project underwent public review through the Trustees Council process. Planning funds were approved by the Trustees in November 1994 at public meeting. Subsequently, a working meeting was held in November to discuss the framework for the project, also an open meeting. The Nearshore Vertebrate Predator Project was presented at January 1995 Trustees sponsored Restoration Workshop in Anchorage. Further opportunities for public input will be available at annual workshops and the Trustee meetings. In addition, volunteer opportunities will exist to assist project biologists in data collection.

revised per 12/11 TC meeting; under peer review-accepted - was 96104

AVIAN PREDATION ON BLUE MUSSELS (*MYTILUS EDULIS*) IN PRINCE WILLIAM SOUND

revised December 1995

Project Number:	96025- FY96 Addendum
Restoration Category:	Research
Proposer:	Copper River Delta Institute, Pacific Northwest Research Station, U.S. Forest Service
Lead Trustee Agency:	U.S. Forest Service
Cooperating Agencies:	USFWS
Duration:	5 years
Cost FY 96:	$131.7
Cost FY 97:	$140.0
Cost FY 98:	$140.0
Cost FY 99:	$60.0
Geographic Area:	Prince William Sound
Injured Resource:	Sea otters, harlequin ducks, blue mussels

ABSTRACT

The nearshore vertebrate predator project, EVOS 96025, hypothesizes that prey availability of invertebrates such as blue mussels has declined and could be constraining recovery of sea otters and harlequin ducks. This project will investigate in oiled and unoiled areas the confounding effects on mussel and sea urchin populations by avian co-predators that are currently not being studied. These include surf scoters, glaucous-winged gulls, black oystercatchers, and surfbirds. This project will gather information on the numbers and distribution of avian co-predators, and how their consumption of mussels and sea urchins effects food availability to sea otters and harlequin ducks in oiled and unoiled areas.

INTRODUCTION

The Nearshore Vertebrate Predator Project (NVPP), EVOS 95025, hypothesizes that prey availability may be limiting the recovery of sea otters (*Enhydra lutris*), river otters (*Lutra canadensis*), pigeon guillemots (*Cepphus columba*), and harlequin ducks (*Histrionicus histrionicus*). The authors suggest that blue mussels (*Mytilus edulis*) and other invertebrate prey species of sea otters and harlequin ducks have declined as a result of the *EXXON Valdez* oil spill. At the same time, sea urchins (*Strongylocentrotus droebachiensis*), a favored food of sea otters, may be increasing in areas oiled due to reduced sea otter predation. To test these hypotheses, the NVPP study will compare recruitment, growth rates, abundances and size-frequency distributions of blue mussels, sea urchins, and other selected invertebrates in oiled areas (northern Knight Island) with those in unoiled areas (northwest Montague Island); and it will assess the effects of co-predators (sea stars and sea ducks) on these invertebrate populations (Holland-Bartels 1995). The following proposal will investigate in oiled and unoiled areas the confounding effects of avian co-predators on two species of invertebrates: blue mussels and sea urchins.

The NVPP proposal suggests that differences in mussel and urchin prey abundances and size distributions are due to process "filters" including recruitment, growth rates, and predation. Recruitment processes and invertebrate predators (eg. sea stars) function similarly by influencing the supply of mussels and urchins available to vertebrate predators. The vertebrate predator "filters" (sea otters and sea ducks), in turn, significantly effect both population abundance and size structure of mussels and sea urchins (see Figure 8, page 80, Holland-Bartels 1995).

To assess the role of birds in structuring mussel populations and their possible confounding effects on interpretation of the effects of sea otter predation, the NVPP project will determine the winter diets of two sea duck co-predators: Barrow's goldeneye (*Bucephala islandica*) and white-winged scoter (*Melanitta fusca*). Analysis of stomach contents collected from wintering goldeneyes and scoters will be used to determine the abundance and size distribution of mussels in the diets. Complete counts of sea ducks will be made at the Knight and Montague Island study sites to determine predation pressures. Ultimately, models including diet, duck numbers, and estimates of caloric needs will be derived to estimate numbers, biomass, and size classes of invertebrate prey that are consumed. At the same time, field data on invertebrate population patterns will be compared with hypothetical patterns to ascertain how food-related factors constrain recovery of sea otters and sea ducks (Holland-Bartels 1995).

Shorebirds and gulls are also important co-predators of mussels and can effect the structure of mussel populations. Marsh (1986a) found that black oystercatchers (*Haematopus bachmani*), surfbirds (*Aphriza virgata*), glaucous-winged gulls (*Larus glaucescens*) and western gulls (*Larus occidentalis*) significantly reduced recruitment of juvenile mussels (mussels < 20mm) into populations inhabiting the outer Oregon coast. In addition, predation intensity by these avian species was disproportionately greater in areas where high densities of prey occurred. Wintering Eurasian oystercatchers (*Haematopous ostralegus*) in England removed 25% of the most productive size classes of blue mussels (30-60 mm)

before they spawned (Goss-Custard and Durrell 1984) and selected larger mussels preferentially over smaller mussels (Cayford and Goss-Custard 1990).

In Prince William Sound (PWS), shorebird and gull co-predators are abundant and could significantly alter interpretation of the effects of sea otter predation in the oiled and unoiled areas. These avian co-predators could also be reducing prey availability in the oiled areas. In the rocky intertidal habitat of Prince William Sound, black oystercatchers, glaucous-winged (GW) gulls, surfbirds, and surf scoters (*Melanitta perspicillata*) commonly forage on blue mussels. Black turnstones (*Arenaria melanocephala*) and harlequin ducks in PWS also forage on mussels to a lesser extent. Although research on glaucous-winged gulls in PWS has been confined to areas with Pacific herring (*Clupea pallasi*) spawn, in the western Aleutian Islands sea urchins, when available, are their primary food. This proposal will investigate the confounding effects of these avian co-predators that are currently not being studied in oiled and unoiled areas of PWS.

All of these avian co-predators occur annually in relatively high numbers in the northwest Montague Island NVPP control area. Black oystercatcher flocks overwinter in this area and GW gulls, surfbirds, surf scoters, and black turnstones occur in the thousands each spring, usually in association with Pacific herring (*Clupea pallasi*) schools (GW gulls only) or spawn deposition (Bishop et al. 1995). Within the control area herring spawn events have occurred during 13 of the past 15 years.

At the northern Knight Island study site, less information is available on the abundance and distribution of this suite of avian co-predators on *Mytilus* and sea urchins. A glaucous-winged gull colony is located at the east end of the Bay of Isles (US Fish and Wildlife Service 1993). Since 1989, US Fish and Wildlife Service (USFWS) marine bird and mammal transects conducted during March and July both at Herring Bay and Bay of Isles (n=3 shoreline transects per site) have recorded black oystercatchers, surfbirds, GW gulls, harlequin ducks, and surf scoters and black turnstones (March only). Of these, harlequin ducks and GW gulls are the two most abundant species, with most observations occurring at Bay of Isles on the July transects.

Three avian *Mytilus* and/or sea urchin predators in PWS are common to abundant year-round residents: harlequin ducks, surf scoters, and GW gulls. These species are more numerous from mid-April to mid-May, due to an influx of migrants (surf scoters and GW gulls) or localized movements (harlequins). While harlequin ducks historically wintered in the Port Chalmers-Graveyard Point area, large numbers of harlequins (300-700) have also been documented between Graveyard Point and Montague Point as late as 19 May (Bishop et al. 1995). Although few harlequins occur in Herring Bay in spring, at Bay of Isles as many as 91 harlequins have been recorded during both Alaska Department of Fish and Game (ADF&G) harlequin duck surveys in late May and USFWS marine bird surveys in July (D. Rosenberg, ADF&G, pers. comm.; S. Kendall, USFWS, pers. comm.). Use of *Mytilus* by harlequins varies by season and locality (Vermeer 1983, Patten et al. in review). In PWS, approximately 12% of the harlequin diet is *Mytilus* ranging in size from 5-15 mm (Patten et al. in review).

Approximately 50-100+ surf scoters occur each March on two USFWS nearshore surveys in the northwest Montague control area with much lower numbers (0-6 birds) on transects at Herring Bay and Bay of Isles. From late April through mid May, large rafts of sea ducks, comprised primarily of surf scoters regularly appear at northwest Montague Island. In 1989 and 1992 Martin (pers. comm.) recorded 1,500 and 600 surf scoters respectively during one day surveys of the northwest Montague NVPP control area. More recently, Bishop et al. (1995 and unpubl. data) documented 3,350-4,400 sea ducks in 1-3 rafts between Rocky Bay and Graveyard Point. Patten et al. (in review) collected surf scoters in PWS between 1989-1990 and found *Mytilus* ranging in size from 10-40 mm in 38% (n=8) of the proventriculus samples. In British Columbia, Vermeer (1981) found that bivalves constituted the main food of surf scoters, except where herring eggs dominated the birds' diet in spring. *Mytilus* ranging in size from 6-40 mm were the primary prey and comprised 56-96% of the percent wet weight of prey items at four study locations. Daily net food consumption (minus shells) was estimated at 196 g/day.

GW gulls, a major *Mytilus* and sea urchin predator, occur throughout spring at the NVPP study sites. At Bay of Isles on Knight Island, GW gulls are the second most abundant marine bird species on July USFWS transects and breed at the east end of the Bay (USFWS 1993). In 1993, Andres (USFWS, pers. comm.) estimated approximately 40 pairs of GW gulls nesting at this colony. USFWS July transects at Bay of Isles have recorded as many as 155 GW gulls on 3 transects in 1989. At northwest Montague Island, historically, large numbers of glaucous-winged gulls have been observed in areas with herring schools and herring spawn. Aerial surveys (n=3) conducted in spring 1994 by Bishop et al. (1995), documented gull numbers ranging between 15,600-25,700 prior to spawn initiation at Montague Island. Some 89-95% of the gulls were concentrated between Stockdale Harbor and Zaikof Bay where herring schools were located.

Where Irons et al. (1986) studied GW gull foraging behavior in the intertidal zone of the Aleutian Islands, gulls concentrated foraging efforts in the lowest intertidal zones available and fed on a large variety of organisms: sea urchins, limpets, chiton, barnacles, and mussels (Irons et al. 1986). Gulls air-dropped large sea urchins to crack the shell or pecked out the Aristotle's lantern to extract the viscera and gonads. Smaller sea urchins and *Mytilus* are swallowed whole (Trapp 1979, Irons 1982). GW gulls generally selected medium sea urchins (30-55 mm) that could still be swallowed whole and (20-35 mm) blue mussels (Irons 1982). Sea otters appeared to effect GW gull foraging behavior in the Aleutian Islands by altering their prey base. In areas where sea otters depressed invertebrate numbers in the intertidal zone, fish comprised a larger component of the GW gull diet (Trapp 1979; Irons 1982; Irons et al. 1986). In areas where sea otters did not occur or occurred in lower numbers, gulls foraged selectively on high energy food sources such as urchins and chitons (Irons 1982).

Sea urchins and *Mytilus* spp. have also been documented as primary food items for breeding gulls, including GW gulls. At two islands on the western Aleutians with extensive intertidal areas and GW gull colonies, sea urchin was the most common invertebrate in the diet, occurring in >70% of the pellets (Trapp 1979, Irons 1982). Pierotti and Annett (1991) suggested that herring gull (*Larus argentatus*) *Mytilus* specialists select mussels because they contain nutrients (calcium and manganese) and amino acids (sulfonated amino) that are

crucial for reproduction and early stages of bone development, respectively. In a study of GW gull breeding colony at Aialik Bay near Seward Alaska, Murphy et al. (1984) found that during their first field season blue mussels were the predominant food item before egg laying and remained important throughout the egg-laying period. The following season mussels were important during the first several weeks of chick hatching. During egg-laying, they recovered one adult GW gull with approximately 150 mussels in its stomach, ranging from 6-26 mm. Similarly, Vermeer (1982) studied five GW gull breeding colonies in British Columbia, and found that *Mytilus edulis* and *Mytilus californianus* were the principal intertidal foods of adult gulls during the egg-laying and incubation stages. Size of *Mytilus edulis* taken by breeding adults ranged from 12-66 mm, and averaged 38 mm in length.

Besides sea ducks and gulls, shorebirds are important *Mytilus* predators in PWS. Black oystercatchers are common throughout PWS in the summer and some remain year-round; 25% of the PWS breeding population remains in PWS in the winter. Two flocks numbering 40 and 30 black oystercatchers overwinter at Stockdale Harbor and Port Chalmers, respectively (Andres 1994). In contrast to other avian predators that ingest mussels whole, black oystercatchers stab gaping mussels and extract mussel meat from the shells. In PWS, mean size of *Mytilus* taken by breeding adults was 32.7 mm (n=1727, by shell collections (Andres and Falxa 1995). While feeding observations on non-breeders are limited, in August 1992 Andres (unpubl. data) observed a flock of post-breeding oystercatchers in Port Chalmers foraging on *Mytilus* at a rate of 1.12 mussels/minute (n=15 birds, 82.8 minutes of observation). Wintering ecology of black oystercatchers has not been studied in PWS. In British Columbia, flocks of wintering black oystercatchers fed exclusively on blue mussels ranging from 20-75 mm and tended to winter in areas of high mussel density. Wintering oystercatchers tended to frequent the same mussel beds (Hartwick and Blaylock 1979).

Black turnstones and surfbirds, both *Mytilus* predators, are abundant migrants in PWS each spring. In 1989, northern Montague Island was discovered to be a critical spring staging area for surfbirds and black turnstones (Norton et al. 1990; Martin 1994). Although total numbers using the Montague area are not known, in May 1992 a single day count of almost 56,000 surfbirds and 25,000 black turnstones was recorded. As many as 11,460 surfbirds have been recorded at one time in the Stockdale Harbor area, 3,500 at Port Chalmers, and 20,352 around the Graveyard Point area (P. Martin, USFWS pers. comm.). Both surfbirds and black turnstones show a positive association with the presence of herring spawn. Both species, however, have also been observed in high numbers in areas on northern Montague Island without herring spawn (Bishop et al. 1995).

During migration, both black turnstones and surfbirds feed throughout the tidal cycle with the highest proportion of birds feeding at low tide, concentrating their foraging within 1 m of the tideline (Bishop et al. unpubl. data). Whereas black turnstones are generalists, preying on mobile crustaceans, polychaetes, and infrequently on mussels (Connors 1968, Marsh 1984), mussels typically comprise a large portion of the surfbird diet. Martin (1994) and Bishop et al. (unpubl. data) analyzed esophagus contents from 12 and 20 surfbirds, respectively, collected while feeding in herring spawn areas at northern Montague. Blue mussels ranging from 4-15 mm were found in 81% (n=32) of the samples. In a study of surfbird diet in Oregon, Marsh (1984) found that *Mytilus edulis* and *M. californianus* ranging up to 15 mm were taken at a higher frequency than predicted by their relative abundance. In southern

Chile, Navarro et al. (1989), found that mussels (*Semimytilus algosus* and *Perumytilus purpuratus*) predominated in the surfbird diet. Medium-sized mussels 6-12 mm were frequent in their diet, whereas larger mussels (12-20 mm) were rare.

NEED FOR THE PROJECT

A. Statement of Problem

The Nearshore Vertebrate Predator Project (NVPP), EVOS 95025, hypothesizes that prey availability is constraining recovery of sea otters and harlequin ducks. They suggest that important invertebrate prey species, including blue mussels have declined as a result of the *EXXON Valdez* oil spill. At the same time sea urchins, a favored food of sea otters, may be increasing in oiled areas due to reduced sea otter predation. Differences in abundance and size structure of blue mussels and sea urchins at oiled and unoiled sites may be due to predation by sea otters and co-predators. Surf scoters, glaucous-winged gulls, black oystercatchers, surfbirds, and black turnstones are major co-predators on *Mytilus* and sea urchin (gulls only) populations. To date we have neither information on numbers nor on distribution of these species at the study sites nor how predictable or how variable is their use of *Mytilus* and sea urchins. At the same time, field experiments are needed to evaluate sea otter and avian predation on mussel and sea urchin density and size distribution. We propose to determine consumption of avian co-predators through non-destructive collections, surveys, and observational studies. We will also test the feasibility and effectiveness of predator exclosures. If predator exclosures are a viable tool, they will be used to determine the effect of predation in structuring invertebrate populations in oiled and unoiled areas.

B. Rationale

As part of the current NVPP study, information on the numbers and diets of sea otters and wintering sea ducks will be collected at the two NVPP study sites. Information collected on mussel abundance and size distribution at these sites will be integrated with co-predator diet information to produce a range of expected prey population characteristics for oil and unoiled areas. Comparison of the field data between these areas will provide improved understanding of food availability, and how it may be constraining recovery of sea otters and sea ducks (Holland-Bartels 1995).

Sustained predation by wintering flocks of black oystercatchers, short-term massive predation each spring by avian co-predators at Montague Island, and sustained predation by breeding GW gulls and resident harlequin ducks at the Bay of Isles study area may be structuring *Mytilus* and sea urchin populations. Because of the association of many of these species with herring schools and spawn (Bishop et al. 1995), changes in the availability or location of herring could lead to different foraging strategies and prey choice at the northwest Montague Island study site. Areas with herring schools or spawn could attract more predators and thus increase predation on mussels and sea urchins. Or conversely, presence of herring spawn could cause co-predators to switch to the more easily obtained spawn, thus making mussels, sea urchins, and other invertebrate prey more available to sea otters and harlequins. An understanding of foraging behavior of avian co-predators is important to understand prey

structure differences between oiled and unoiled areas and determine if food availability is constraining vertebrate recovery in oiled areas.

For sea urchins, NVPP proposes to collect data on abundance, size distribution, growth rate, and recruitment and compare data from unoiled sites with large numbers of sea otters with oiled sites and few sea otters. NVPP suggests that sea urchins, a favored food of sea otters, may be increasing in areas oiled due to reduced sea otter predation. Comparing the foraging strategies and diets of GW gulls at Montague Island and Bay of Isles will provide an opportunity to validate that sea urchins have increased at oiled sites. If sea urchins have increased in availability at oiled areas, we would predict that glaucous-winged gulls will forage selectively on sea urchins; relative to other potential prey, urchins provide high energy food source (Irons 1982).

The resources to be studied by this project are six avian predators on blue mussels (black oystercatchers, glaucous-winged gulls, surfbirds, black turnstones, surf scoters, harlequin ducks). Populations of blue mussels, harlequin ducks, and black oystercatchers were injured as a result of EVOS. Ecologically, blue mussels are an important food resource for large numbers of invertebrates, sea otters, and birds, including black oystercatchers, and harlequin ducks. Sea urchins are an important food resource for invertebrates (sea stars), sea otters, and glaucous-winged gulls.

C. Summary of Major Hypotheses and Objectives

Our research hypotheses are:

1. Avian co-predators significantly reduce mussel abundance in size classes <40mm.

2. Areas used frequently by avian co-predators correspond to high mussel densities.

3. Consumption of mussels by avian co-predators decreases when herring spawn is available.

4. Mussel size class distribution differs between avian predator foraging and nonforaging areas. In areas where avian predators do not forage, sea otters and sea star predators structure mussel populations.

5. Glaucous-winged gull consumption of sea urchins is positively correlated to sea urchin density.

PROJECT DESIGN

A. Objectives

The objectives of this study are:

1. Determine if differences exist between oiled and unoiled areas with respect to the distribution and abundance of avian *Mytilus* predators.

2. Compare rates of food intake, size selection, and total consumption of mussels by avian co-predators at oiled and unoiled NVPP study areas.

3. Determine if differences exist between oiled and unoiled areas in abundance or size distribution of prey in avian foraging habitats.

4. Compare sea urchin consumption and size selection by glaucous-winged gulls at oiled and unoiled NVPP study sites.

1. Study area

The study area consists of the NVPP study areas at northern Knight Island (Herring Bay and Bay of Isles) and northwest Montague Island (Port Chalmers to Graveyard Point). These study areas coincide with the study areas of the Sea Duck and sea otter component of NVPP.

2. Data collection

a. Distribution, Timing, and Abundance of Avian Predators

Winter surveys.

Information on the winter abundance and location of avian co-predators of *Mytilus* and sea urchin in oiled and unoiled areas will be provided by the NVPP Sea Duck component. In December and March, one or more replicate surveys for all birds and sea otters will be conducted at northern Knight Island and northwest Montague Island (T. Bowman, USFWS, pers. comm.).

Spring/Summer surveys.

Distribution, timing, abundance and species composition of avian co-predators foraging in oiled (Knight Island) and unoiled (Montague Island) areas will be determined by shoreline and offshore boat surveys during three seasons. At Montague and Knight Islands field work will be conducted from 15 April to 25 May, and 5-20 July. For each field season, surveys will be conducted every other day, weather permitting, at Montague Island, and twice weekly at Bay of Isles, and weekly at Herring Bay.

Because shorebirds tend to roost during high tides on offshore rocks and GW gulls concentrate their foraging efforts in the lowest intertidal zone (Irons 1982), shoreline surveys will be conducted between the 2 hr before and after low tide when the maximum amount of intertidal zone is available for foraging. An area within 120 m of shore, as well as shoreline (maximum shoreline width 50 m) will be surveyed with a boat running a course 20 m from

shore at approximately 5 knots. A 20 m offshore course (versus the 100 m offshore course that the Sea Duck component use) is required because of the small size and cryptic plumage of surfbirds and black turnstones.

Offshore transects will be surveyed after completion of the shoreline surveys using the same methodology as NVPP's Sea Duck offshore surveys. Offshore transects will be 200 m wide and oriented perpendicular to the shoreline at 500 m intervals. In Herring Bay and Bay of Isles, the offshore stratum includes all waters inside the mouth of the Bay. At the Montague Island study site, offshore transects extend outward from land to the 20 m depth contour (T. Bowman, USFWS, pers. comm.).

Both the shoreline and offshore area will be surveyed using methods adapted from the USFWS marine birds and mammal surveys (USFWS 1991). While the boat is moving along the survey route, all birds and sea otters are counted within a "window" that extends 100 m on the seaward side, 20 m+ on the shoreward side (100 m each side for offshore transects and winter black oystercatcher high tide surveys), 50 m ahead, and 100 m above the boat. Birds moving into the survey window from behind are ignored. Two observers (1 driver/observer, 1 observer/recorder) will be assigned to survey each side of the boat.

Species surveyed include sea otters, surf and white-winged scoters, barrow's goldeneyes, harlequin ducks, surfbirds, black turnstones, GW gulls, and mew gulls. Data collected for all boat surveys will include: number and species (or genus), location, herring spawn (presence, absence) shoreline type (exposed rocky, sheltered rocky, exposed wave-cut platforms, gravel beaches, sheltered tidal flats), habitat (mussel bed, all other land, water, air), and behavior (forage, dive, fly, other). Locations of observations will be recorded on aerial photos using mylar overlays. Data will be recorded on Husky data loggers with Dictaphone voice recorders as a backup system. Data logger files will be downloaded onto a computer harddrive and diskettes.

b. Avian Effects on Mussel and Sea Urchin Populations

To assess how avian and sea otter predation are structuring mussel and sea urchin abundance and size distribution, we will determine and compare avian consumption of mussels and sea urchins in oiled and unoiled areas. The NVPP Sea Duck component will determine mussel consumption for wintering sea ducks.

In FY96, a preliminary experiment will be conducted to test the feasibility and effectiveness of predator exclosures. Pending successful results, in FY97 we will assess direct avian predator and sea otter effects on mussel and sea urchin density and size distribution using exclosure experiments in oiled and unoiled areas. Using a model based on proportion of birds foraging and intake rates across the tidal cycle, we will determine an estimate of total blue mussels and sea urchin biomass removed from oiled and unoiled areas by avian co-predators.

Exclosure Experiments.

For FY96 a preliminary experiment will be conducted to test the feasibility and effectiveness of predator exclosures including cage artefacts. The preliminary experiment will be conducted in northern Orca Inlet from February through September 1996.

Two types of treatments will be tested for feasibility and cage effects. The first treatment will consist of a square exclosure made of rebar, pressed 30cm into the substrate and extending 15cm above the mussel bed. An exclosure "lid" will be made of 1.5 -2 cm plastic-coated hardware cloth (eg. vexar). The exclosure will have open sides to allow access to sea otter, sea-star, whelk (Nucella sp.) and crab predators but will exclude avian predators. The second treatment will consist of a same sized exclosure, but with side access 2-3cm above the mussel bed. This will allow access to invertebrates but exclude birds and sea otters. A third treatment will be the control consisting of an area marked by a single stake.

Two sizes of exclosures will be tested: 50 cm x 50 cm and 1 m x 1 m. Same-sized exclosures will be arranged in blocks containing all three treatments. Each block of three treatments will be at the same tidal elevation, separated by 2 m. This block design will attempt to expose all treatments to similar predation pressure. At the same time, treatments in close proximity will most likely have similar mussel densities. The 2 m separation between treatments will also assure that foraging birds use uncaged sites.

At Orca Inlet, three replicate blocks of each size exclosure (N=6 blocks) will be distributed in an intertidal area frequented by sea otters. Blocks will be checked 3-4x weekly and the following data will be recorded for each exclosure and control: extent of fouling, scouring, and sediment accumulation, evidence of predation and predators present (invertebrates within a 2m radius around the center of the frame and vertebrates within a 50m radius). Each block will be cleaned of any debris or fouling on a preassigned schedule of either 3-4x weekly, every 2 weeks, or once a month. In this manner we can evaluate the conditions that produce and the duration of cage effects.

We will experiment with cage effectiveness in excluding sea otters (treatment 2) and sea otter use of exclosures (treatment 1) using preferred foods as bait. Twice monthly from February through September dungeness crabs will be placed in all treatments. One crab will be placed per exclosure on a rising or falling tide (once, bimonthly for each tide)in the exclosures designed to allow access to sea otters. Observations from a parked vehicle will be made of all animal activity in the area of the exclosures for a 6 hr period. Observation periods will vary by time of day in order to detect use of exclosures by non-target species including mink. The following data will be recorded when any animal interacts with an exclosure or a control: time, block/treatment number, species, behavior (forage, dive, rest, comfort, alert, agonistic), prey attack and ingest events, and prey type. The data will be recorded using Psion LZ64 dataloggers and The Observer (ver. 3.0, Noldus Information Technology, Wageningen Netherlands), a behavior recording computer program. Since we cannot directly observe the interactions of animals diving on the treatments, the same data will be recorded for any animal diving within 15m of an exclosure as a possible interaction. Additionally, scan samples of all animals within a 100m x 100m area around each block will be made every 30 min. The following will be recorded: species, number, behavior (forage,

dive, and other), habitat (mussel or sea urchin habitat, all other land, water, air) and distance from the tideline. Birds flying through the scan area without stopping or milling will be ignored.

Foraging Behavior.

Foraging behavior of *Mytilus* and sea urchin predators in relation to *Mytilus* and sea urchin abundance and distribution across the intertidal zone will be determined using focal animal and scan observations (Altman 1974). Observations will be made at Montague Island and northern Knight Island (Bay of Isles) during both field seasons.

Locations of foraging sites will be recorded on aerial photos using mylar overlays. During spring at Knight and Montague Islands, foraging observations will be conducted at six plots frequented by foraging birds. Plots 50m x 100 m will extend shoreward from the tideline. Observations will be made from a camouflaged blind over a 6 hour period (1 tidal cycle), alternating between high and low tidal cycles.

Scan observations will be collected every 30 minutes. For each scan sample, the following information will be recorded: number and species of birds and sea otters by activity, shoreline type, habitat (mussel or sea urchin habitat, all other land, water, air), and bird location in relation to the tideline. Activity classes include foraging and non-foraging. Birds flying through the scan area without stopping or milling will be ignored.

In between scan samples, focal animal sampling (Altman 1974) will be used to gather information on food intake rates and mussel sizes captured. Individuals in foraging flocks will be randomly selected for observations; each focal individual will be observed for a minimum of 15 min or until the bird is lost. Focal animal data will be recorded continuously using Psion LZ64 dataloggers and The Observer (ver. 3.0, Noldus Information Technology, Wageningen Netherlands), a behavior recording computer program. Information recorded will include: activity (foraging, nonforaging), meters above tideline, habitat, search and handling times for each prey item. Prey items will be identified to the lowest taxonomic level possible and the mode of consuming prey (eg. ingested whole, extracted) will also be recorded. For black oystercatchers, GW gulls, and surfbirds, size determination of mussels and sea urchins consumed is possible in the field (Irons 1982, Andres 1991, Cayford and Goss-Custard 1990, Bishop et al. unpubl. data) and will be recorded.

Food Habits-Gulls.

Gulls regurgitate pellets are composed of large undigestible hard parts of prey. For the 1996 field season, at Bay of Isles regurgitated pellets from GW gull nesting territories will be collected once a week during spring to determine mussel consumption. Post-hatch, regurgitations from chicks will be collected once per nest by inserting a finger down the chicks' throats and hooking it behind the contents of the proventriculus (Vermeer 1982). Because repeated searches at scan plots could damage mussel beds and sea urchin aggregations, we will collect gull pellets opportunistically at Montague Island. Pellets and regurgitants will be stored in alcohol.

Mussel and Sea Urchin Consumption Models.

The mussel and sea urchin consumption models will be used to determine the effects of avian co-predators on mussel and sea urchin abundance available to sea otters at oiled and unoiled sites. For each avian predator, three values must be determined for the proposed consumption models: the number of birds present in mussel or sea urchin areas, proportion of birds foraging on *Mytilus* or sea urchin, and the *Mytilus* or sea urchin intake rate per size class.

Number of bird days in mussel beds and sea urchin aggregations will be determined from shoreline and offshore surveys. Locations of mussel beds and sea urchin aggregations will be provided from the Mussel and Sea Urchin components of the NVPP.

Proportion of birds foraging on *Mytilus* beds or sea urchin aggregations across the tidal cycle will be determined from scan samples. The *Mytilus* or sea urchin intake rate per size class will be determined from focal animal samples. GW gull pellets and chick regurgitations will be used to validate diet composition and size class of *Mytilus* and sea urchins consumed.

3. Data analysis

a. Distribution, Timing, and Abundance of Avian Predators

Estimates of numbers and species composition of avian predators will be based on shoreline boat surveys. Bird days for each species will be calculated. Using data from boat surveys, the timing and abundance of avian predators in mussel beds and at sea urchin aggregations will be graphed by plotting abundance by calendar date. Estimates of avian abundance between survey days will be determined by linear interpolation.

A linear model will be tested to determine the relationship between bird densities and the following variables: shoreline type, location, mussel and sea urchin abundance (provided by mussel and sea urchin components of 95025) and presence or absence of herring spawn (Montague Island only, data provided from ADF&G aerial surveys). If a linear model is not appropriate, we will test a generalized linear model. From this model we will be able to predict areas where avian co-predators could have a significant impact on prey availability for sea otters.

b. Avian Mussel Consumption

Exclosure Experiments.

Exclosures will be evaluated for cage effects. The percent occurrence and extent of fouling, sedimentation, and scouring will be determined for each treatment block. In this manner we can estimate how often exclosures must be checked during year 2 of the experiment. Effectiveness of treatments will be evaluated based on number of observations per hour of sea otters in close proximity ($<=$ 15m) to the exclosures. In addition, occurrence of any sea otter or other vertebrate predator using treatments 1 and 2 will be determined.

Foraging Behavior and Food Habits.

For scan samples, we will use Kruskall-Wallis non-parametric one-way analysis of variance to determine if there is a difference in the mean proportion of a species feeding: a) by tide; b) by tide direction; and c) by low tide height. A stepwise generalized linear model will be used to relate the proportion of a species feeding with a suite of environmental variables including: location, tidal zone, tide height, tide, tide direction and habitat.

For focal animal samples, *Mytilus* intake rates will be analyzed by species. Again, we will use Kruskall-Wallis non-parametric one-way analysis of variance to determine if there is a difference in intake rate in relation to the tidal cycle (tide and direction). Focal animal samples will also be analyzed for percent occurrence of prey items. Standard t-tests will be used to determine significant differences in sizes of mussels and sea urchins captured by co-predators at oiled and unoiled sites, and capture rates/min by species between locations and across seasons.

Diet analysis from chick regurgitations will consist of sorting and identifying samples and quantifying length, width, and wet mass of each item and wet mass, volume, and dry mass of each taxa per sample. Regurgitated pellets will be analyzed for occurrence and aggregate weight of prey species and measurable parts will be examined to determine prey size.

Mussel and Sea Urchin Consumption Models.

For each day and species, we will calculate overall *Mytilus* (or sea urchins) intake (*OI*) during daylight hours (from 1 hour before to 1 hour after sunset) using the following equation:

$$OI = \sum_{i=1}^{n} B \cdot F_i \cdot IR_i \cdot D_i$$

where:

i = tidal cycle interval
B = total number of birds per day in *Mytilus* areas
F_i = mean proportion of birds foraging on Mytilus
IR_i = mean *Mytilus* intake rate
D_i = proportion of interval during daylight hours

If there are no significant differences in the mean proportion of a species feeding by tidal cycle (see foraging behavior analyses above) the overall mean proportion will be used. Similarly, if there are no significant differences in the mean *Mytilus* intake rate by tidal cycle, the overall mean rate will be used.

C. Contracts and Other Agency Assistance

Oregon State University or the Cooperative Fish and Wildlife Research Unit at University of Alaska will be contracted to develop *Mytilus* and sea urchin consumption models. S. Patrick Green will conduct this portion of the study in fulfillment of his masters thesis requirement. Green has served as field supervisor for EVOS 95320Q Avian Predation on Herring Spawn and is familiar with this project's goals and logistics.

D. Location

The study area consists of the NVPP study areas at northern Knight Island (Herring Bay and Bay of Isles) and northwest Montague Island (Port Chalmers to Graveyard Point). These study areas coincide with the study areas of the Sea Duck component of NVPP.

SCHEDULE

A. Measurable Project Tasks for FY96

Start-up	Receive mussel and sea urchin data from 95025
Start-up -April 1	Arrange logistics (boats, supplies, contracts)
Feb 1- Sept 31	Exclosure experiments in Orca Inlet
Feb 28	Complete cooperative agreement with university
March 1-10	Hire personnel, order field supplies,
April 1-7	CPR/First Aid, and Boat Safety training
April 15-May 25	Spring field season. Data collection at Montague and Knight Islands
May 1	Complete Detailed Project Description for FY97
May 25-Sept 30	Data entry, diet analysis, begin data analysis
Jul 5-20	Summer field season. Data collection at Montague and Knight Islands
November 30	Data analysis completed
April 1997	Annual report on FY 96 work

B. Milestones

1. Determine if differences exist between oiled and unoiled areas with respect to the distribution and abundance of surfbirds, black turnstones, glaucous-winged gulls, surf scoters, and harlequin ducks during spring.

   Field work winter and spring 1996, 1997, 1998.
   Objective met 1999.

2. Compare rates of food intake, size selection, and total consumption of mussels by avian co-predators at oiled and unoiled NVPP study areas.

   Field work winter and spring 1995, 1997, 1998.
   Masters thesis submitted August 1998.
   Objective met 1999.

3. Determine if differences exist between oiled and unoiled areas in abundance or size distribution of prey in avian foraging habitats.

   Field work winter and spring 1995, 1997, 1998.
   Objective met 1999.

4. Compare sea urchin consumption and size selection at oiled and unoiled NVPP study sites.

   Field work spring 1996, 1997, 1998.
   Objective met 1999.

5. Determine effectiveness of sea otter and bird exclosures.

   Field work winter-fall 1996
   Objective met 1996.

C. Project Reports

This project will be conducted as part of EVOS 96025 and will follow their reporting schedule. In April 1997 it will submitted the 1996 Progress Report along with all other project components.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

No federal or state agency program currently exists that could be described as an ecosystem framework for studying resources in Prince William Sound and the EVOS region. For this project, all aspects of field work for this project are coordinated and integrated with EVOS 96025, the Nearshore Vertebrate Predator Project. Our study areas consist of the NVPP study areas at northern Knight Island (Herring Bay and Bay of Isles) and northwest Montague Island (Port Chalmers to Graveyard Point). These study areas coincide with the study areas of the Sea Duck component of NVPP.

Information on avian co-predators in winter will be provided by the Sea Duck component of 95025. Data will also be provided on the size and species of observed invertebrate prey and as well as prey found in regurgitants and pellets of gulls. We will provide densities and species composition of birds in mussel beds and sea urchin aggregations. All data from this project will be archived by the project staff in accordance with standardized procedures set up for handling the NVPP database. The field results from the avian predation study will be integrated into the NVPP's numerical and analytical models of the PWS ecosystem that include predation parameters and animal distributions.

During FY96 the Copper River Delta Institute will contribute resources in the form of personnel costs for the Project Leader (2 months in-kind) and Assistant Project Leader (1 month in-kind) as well as some field equipment (one inflatable skiff with motor, camping supplies). Ongoing spring shorebird migration studies on the Copper River Delta will provide additional information on the phenology and habitat use of surfbirds and black turnstones.

Other agency contributions to this project include equipment loans from the Cordova Ranger District, Chugach National Forest: one weatherport, one wall tent, and access to their administrative cabin at Port Chalmers.

ENVIRONMENTAL COMPLIANCE

This study primarily involves wire exclosures, and observations and infrequent nondestructive collection of diet information. A scientific permit will be applied for with the US Fish and Wildlife Service and the State of Alaska to collect regurgitants from gull chicks on Knight Island. This study qualifies for a categorical exemption from the requirements of the National Environmental Policy Act.

Kodiak Archipelago Shoreline Assessment: Monitoring Surface and Subsurface Oil

Project Number:	96027
Restoration Category:	Monitoring (continued)
Proposed By:	ADEC
Lead Trustee Agency:	ADEC
Duration:	One year
Cost FY 96:	$39,800
Cost FY 97 and Future Years:	None
Geographic Area:	Kodiak
Injured Resource/Service:	Subsistence, recreation, intertidal and subtidal organisms, all other injured resources and services dependent upon recovery of oiled beaches

ABSTRACT

This project completes work begun in FY 95 to determine the areal extent, toxicity and origin of 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 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. The project will also develop shoreline treatment alternatives for Trustee Council consideration as recommended by the Residual Oiling Workshop held in the fall, 1995.

INTRODUCTION

This project is closeout only. The draft report will have been written in FY 95. However, an important purpose of this project is to create a common understanding among the Trustees, local residents, subsistence and recreation user groups, scientists, and the general public about the presence or absence of *Exxon Valdez* oil in the Kodiak area. This closeout funding will fund travel and meetings to convey the results of the 1995 field work to Kodiak area residents. It will also fund any response to peer review comments on the draft, and final printing.

Data from previous shoreline assessments indicates that 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. 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.

The project also includes two months of personnel time to assess the environmental effects and develop alternatives for shoreline treatment. The task is a result of the Residual Oiling Workshop held November 1-2, 1995. The effects and alternatives are expected to be presented to the Trustee Council in early winter 1995.

A and B. Statement of the Problem and Rationale

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."

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.

Shoreline Treatment Alternatives. Although Kodiak area has proved to have few areas with significant shoreline oil, significant surface and subsurface oil remains Prince William Sound.

shoreline oil, significant surface and subsurface oil remains Prince William Sound. Residents of the Village of Chenega have repeatedly asked the Trustee Council to authorize projects to clean important shorelines of residual surface or subsurface oil. Chenega residents and Corporation collaborated with private firms to submit projects with this objective in FY 95 and FY 96. At the Public Advisory Group meeting on June 13-14, there was a discussion of residual oiling. To provide information to resolve this question, the Residual Oiling Workshop was held on November 1-2, 1995. As a result of this workshop, shoreline cleaning alternatives are being developed for presentation to the Trustee Council in early winter 1996. For more information, please see the Residual Oiling Workshop Report.

C. Summary of Major Hypothesis and Objectives

The objectives of the total project (FY 95 and 96), as modified during FY 95 DPD review, are below:

a. Create a common understanding that does not now exist among the trees, local residents, subsistence and recreational user groups, scientists, and the general public about the presence or absence of *Exxon Valdez* oil in the Kodiak Area. The project should take special concern and focus on areas of community concern with respect to the presence or absence of the oil.

b. Achieve the above objective in such a way that the project provides current information useful for all injured resource and services; that is, the project will update the 1991 information base necessary for other research and restoration in the Kodiak area.

c. Where (and if) surface and subsurface oil is found, the project will locate "hot spots: where continued monitoring, and possible 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 for this area.

d. Maintain (and possible end) the record of the extent, concentration, and degradation of surface and subsurface oil from the 1989 *Exxon Valdez* oil spill in these areas.

Most of these objectives will have been met in FY 95. The only task remaining for FY 96 will be to work with communities to understand the information and determine if anything further needs to be done. That is, only portions of objectives a) and c) remain for FY 96.

e. With respect to alternatives for additional shoreline oil, the objective is to further develop the treatment alternatives with respect to which beaches, benefits, financial costs, environmental costs, and other required information can be presented to the Trustee Council in early winter 1996.

D. Completion Date

All objectives will be complete during FY 96.

COMMUNITY INVOLVEMENT

This project has and will continue to involve the communities of Kodiak Archipelago in two ways:

- *Locating Beaches.* The beaches to be surveyed were located by ADEC in consultation with Kodiak residents. That is, ADEC made a first draft of beaches to survey based on past data. That list was significantly altered during community review in two meetings in Kodiak involving residents of the Municipality Kodiak, residents of the six outlying villages, and discussions with the Mayor's office.

- *Communicating the Results.* ADEC representatives will work with villages to understand and digest the results of the survey. This will involve publication appropriate to citizen readers, and meetings with concerned villagers.

PROJECT DESIGN

The detailed objectives and methodology for FY 95 are not repeated here, because they will have been accomplished before FY 96 begin.

A. Objectives

See discussion under "Need for the Project, Part C. Summary of Major Hypothesis and Objectives."

B. Methods

The FY 96 component of this project has two methods;

1. Publication and distribution of results appropriate for the general public (as opposed to the scientific community).

2. Meetings with communities and interest groups, as appropriate to discuss results. If at all possible, these meetings will occur in conjunction with other Trustee Council activities, rather than as individual meetings. This will better communicate the entire suite of Trustee Council activities as opposed to communicating oiling information only. In addition, it will lower travel and meeting costs, and avoid deluging the communicates with a plethora of scientists and personnel.

C. Contracts and Other Agency Assistance

Not Applicable.

D. Location

Kodiak Archipelago and communities. Shoreline treatment section is for the Chenega area of Prince William Sound.

SCHEDULE

A. Measurable Project Tasks for FY 96

Draft Report	October 1, 1995
Final Report	45 days after peer review comments received. (Most likely before January 1996).
General Public Report	45 days after peer review comments received. Due to the Christmas holidays, it will most likely be distributed in January 1996.
Community Meetings	Because community meetings will take advantage of other Trustee Council activities in the area, it is not possible to schedule them precisely at this time. However, they will be completed between October 1995 and February 1996.

B. Project Milestones and Endpoints

See above.

C. Project Reports

See above.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Not applicable. Except that community meetings will be coordinated with other Trustee Council meetings in the region.

ENVIRONMENTAL COMPLIANCE

NEPA compliance for this project was completed in FY 95.

Development of a Productivity Index to Monitor the Reproductive Success of Marbled and Kittlitz's Murrelets in Prince William Sound, Alaska

Project Number:	96031
Project Category:	Research
Proposer:	Katherine J. Kuletz
Lead Trustee Agency:	DOI
Duration:	3 years
Cost FY 96:	$77,600
Cost FY 97:	$50,000
Cost FY 98:	$39,900
Geographic Area:	Prince William Sound
Injured Resource/Service:	Marbled Murrelet (*Brachyramphus marmoratus*) and Kittlitz's Murrelet (*B. brevirostris*)

ABSTRACT

We propose to develop a means to monitor the productivity of the two *Brachyramphus* murrelets, marbled and Kittlitz's murrelets, in Prince William Sound. The reproductive success of these two non-colonial seabirds can not be monitored using standard techniques. To develop a productivity survey protocol, we will survey murrelets at sea to determine the timing and abundance of juveniles, the ratio of juveniles to adults, and to describe coastal and marine features that best predict juvenile abundance. We will also determine the post-fledging movement of juveniles, to aid the design of a monitoring program. By monitoring murrelet productivity in relation to population trends, this index can eventually be used to determine what factors, including forage fish abundance, influence murrelet recovery.

INTRODUCTION

The marbled murrelet (*Brachyramphus marmoratus*), the most abundant seabird in Prince William Sound in the summer, was a species injured in the *Exxon Valdez* Oil Spill. It's close relative the Kittlitz's murrelet (*B. brevirostris*), is rare, and because a significant portion of their world population breeds in the spill zone, they will probably be added to the list of injured species in 1995.

These two species comprise the *Brachyramphus* murrelets, whose numbers declined significantly since the early 1970's (Klosiewski and Laing 1994).

The goal of this 3-year project is to develop a means to measure murrelet productivity that will enable us to determine if low reproductive success is limiting the recovery of marbled and Kittlitz's murrelets in Prince William Sound. Earlier restoration projects identified marbled murrelet nesting habitat in southcentral Alaska to guide land acquisition efforts (Restoration Projects R15 and 93051B). A 1994 project (94102) determined the foraging ranges of marbled murrelets breeding in Prince William Sound, and identified key marine habitats used by adults during the breeding season. In a related pilot study conducted under project 94102, we investigated the use of at-sea surveys for juveniles at two locations in Prince William Sound (Kuletz et al. 1995). The first year of work to develop a productivity index will begin in 1995.

Although this project was initiated for the marbled murrelet, data for both species can be collected simultaneously if known areas of Kittlitz's concentrations are included in the surveys. With a method of monitoring reproduction of both species, and in conjunction with data from the APEX project (96163), we can eventually examine the hypothesis that food limitation is affecting murrelet productivity. Ultimately we will improve our ability to predict how management options will affect the recovery of these species.

NEED FOR THE PROJECT

A. Statement of problem

The marbled murrelet, as the most abundant apex predator in the Prince William Sound marine ecosystem, could be an important indicator of the health of the marine environment. Because of difficulties distinguishing it from the rare Kittlitz's murrelet, the conspecifics were lumped during surveys of Prince William Sound. Although *Brachyramphus* murrelets suffered high mortality in the *Exxon Valdez* oil spill (Ecological Consulting, Inc. 1991, Piatt et al. 1990, Kuletz 1994), the spill cannot account for the 67% reduction in numbers observed in post-spill years (Klosiewski and Laing 1994). There has been no significant increase in the Prince William Sound murrelet population since 1989 (Agler et al. 1994). Murrelet recovery could be inhibited by low recruitment (juveniles entering the population), but we do not have the data to determine if low breeding success is a problem. Low adult survivorship, due to gillnet mortality or winter mortality outside Prince William Sound, could also be inhibiting murrelet recovery. Without information on productivity, the long-term population trends will not indicate where the problem originates.

Because of their secretive and highly dispersed nesting habits, the reproductive success of these two species can not be followed using standard techniques. By developing a cost-effective index of reproductive success for *Brachyramphus* murrelets, we will be able to examine the physical and biological factors that may influence murrelet productivity. The marbled murrelet, the more abundant of the conspecifics, is a threatened species under the Endangered Species Act in California, Oregon

and Washington, and a Category II species of concern in Alaska. The Kittlitz's murrelet, indigenous to Alaska and the Russian Far East and rare, is also a Category II species of concern.

B. Rationale

South of Alaska, marbled murrelet populations have declined primarily due to the loss of old-growth forest nesting habitat (Stein and Miller 1992). However, a comparatively small proportion of potential nesting habitat has been harvested in PWS. The nesting habitat of the Kittlitz's murrelet, which nests exclusively on the ground at high elevations, should not be threatened by current human activities. Concurrent with murrelet population declines, populations of other apex predators that eat small schooling fish have also declined in Prince William Sound (Frost et al. 1994, Klosiewski and Laing 1994, Oakley and Kuletz 1994). These schooling, or forage fish, on which murrelets depend include sand lance, (*Ammodytes hexapterous*), capelin (*Mallotus villosus*), herring (*Clupeidae spp*) and pollock (*Gadidae spp*) (Oakley and Kuletz 1979, Krasnow and Sanger 1986, Sanger 1987, Kuletz, unpubl. data). The concurrent population declines in Prince William Sound suggest that the murrelet population may be affected during the breeding season, perhaps due to low food availability.

If food is limiting murrelet recovery by affecting their reproductive success, it is possible that recruitment is not replacing adult mortality. Because murrelets are likely long-lived (Beissinger 1995), the effects of low reproduction may not be evident in population surveys for a decade after the perturbation that caused the loss. Thus, the recovery objective for murrelets, to have their populations increasing or stable, may not be measurable in a timely manner with surveys of the adult population alone. Alternatively, trends in the total population estimates might reflect adult survivorship, which might require a different management approach. To effectively monitor murrelet recovery and make appropriate management decisions, requires that we monitor murrelet productivity in addition to population trends.

Despite years of effort throughout their range, few nests of either species have been found to examine reproductive parameters (Nelson and Hamer 1995, Day et al. 1983, Day 1995). Without telemetry, we located 14 nests between 1991 and 1993. In 1993 and 1994 we used telemetry to locate six nests and track the foraging movements of 56 marbled murrelets and 1 Kittlitz's murrelet (Burns et al. 1994, Kuletz et al. 1995). Telemetry provided us with valuable knowledge of murrelet foraging ecology that will be needed to develop a productivity survey protocol. However, locating such low numbers of nests is unlikely to provide a long-term, effective means of monitoring the reproductive health of the population. This project, 95031-97031, will research and develop a protocol to achieve that goal.

C. Summary of Major Hypotheses and Objectives

To meet our objective to develop a murrelet productivity index, we will survey murrelets at sea at 6 locations in Prince William Sound over 3 years, to compare among-site and annual variation of several parameters. These parameters will be the timing and absolute abundance of juveniles, the ratio of juveniles to adults, habitat associations, and juvenile movement during July and August. We will test

the hypothesis that temporal and spatial variability in juveniles will be convergent among sites during the 3 years. We will examine the relationship between juvenile abundance and the marine environment / coastal features to determine what combination of features influence juvenile abundance.

D. Completion Date

The third year of field work in FY 97 will complete the research to develop the protocol for a murrelet productivity index. The final report for this project will be completed in FY 98.

COMMUNITY INVOLVEMENT

Murrelets are not used for subsistence by local communities. They are, however, subject to gillnet mortality (Wynne et al. 1992, Carter 1995). Gillnet by-catch, and observations by fishermen, could identify areas with high juvenile murrelet activity or concentrations of post-breeding adult murrelets. Additionally, dead juveniles have been found on land and at sea in late summer by residents. In 1994, we displayed a poster soliciting murrelet carcasses for study skins in Whittier and Cordova, and local residents contributed a few samples. This effort will be continued in 1995 at other communities in Prince William Sound.

PROJECT DESIGN

A. Objective

1. Develop an index of marbled and Kittlitz's murrelet reproductive success for Prince William Sound by:

    a. Determining the timing and abundance of juveniles on the water relative to numbers of adults.

    b. Determining what environmental factors influence the abundance and distribution of juvenile murrelets at sea.

    c. Determining the post-fledging movement of juveniles.

B. Methods

Study Area.-- The study area will be Prince William Sound, using the same sites surveyed in 1995 - Valdez Arm, Unakwik Inlet, Naked Island, central Port Nellie Juan, northern Knight Island, and Jackpot Bay / Dangerous Passage (Fig. 1). These areas were selected because they have sufficient

numbers of murrelets and at least four of them will be surveyed by forage fish studies to be conducted in 1995 - 1997. They are also separated by approximately 16 km, which is the average direct-line distance traveled between feeding and nest sites by murrelets in PWS, and twice the distance that the tagged juvenile murrelet moved from its nest over a 2 week period (Kuletz et al. 1995).

Background. -- Ideally, a reproductive index would be ground-truthed by an independent measure of reproduction. One type of independent test would be to follow the reproductive success of individual murrelet nests; nests could be located by ratio-tagging adults and using telemetry to find nests and monitor their outcome. This method is expensive and, to date, has only provided a small sample size. The productivity of other seabirds, such as the pigeon guillemot or black-legged kittiwake, may serve as indicators of general environmental conditions, but may not always be indicative of murrelet reproductive success. Pigeon guillemots feed on a variety of bottom fish not used by murrelets, and thus the effect of changes in surface schooling fish abundance on guillemot reproduction may be less drastic than for murrelets. Kittiwakes are surface feeders and would not have access to fish in deeper water. In this study, we will ground-truth the murrelet productivity index by making among-site comparisons over 3 years.

Because murrelets can not be counted at their nests, researchers at lower latitudes have attempted to use the ratio of marbled murrelet juveniles to adults at sea as an index of reproductive success (Beissinger 1995, Ralph and Long 1995). Juvenile murrelets, once fledged, are on their own and usually solitary, or mix with adults at feeding areas in late summer (Sealy 1975, Sealy and Carter 1984). The problems that arose included: (1) Juveniles were difficult to distinguish from adults in winter plumage, particularly after late August (Carter and Stein 1995). (2) The best time to survey was not well defined, because murrelets were not as highly synchronized as colonially breeding seabirds (De Santo and Nelson 1995) and juveniles fledged from late May to late September (Hamer and Nelson 1995). (3) The post-fledging movements of juveniles and adults were unknown, and there was no independent measure of the total population; thus the interpretation of counts or ratios was subject to error. (4) The number of juveniles on the water was low (2-5%; Beissinger 1995, Ralph and Long 1995) and the number of adults was also low, so that obtaining sufficient numbers of birds per survey for rigorous analysis was unlikely.

In 1994, as part of restoration project 94102 (Kuletz et al. 1995), we conducted a pilot study to survey juvenile murrelet counts at two sites in PWS - Naked Island and Port Nellie Juan. Peak numbers of juveniles were observed from 9 - 29 August, during which time the total number of murrelets declined sharply, as adults appeared to leave both areas. The post fledging movements of 1 chick we radio-tagged at its nest suggested that juveniles remain in the general vicinity ($<$ 12 km, and remaining in a 10 km^2 area) of the nest for at least 2 weeks. With peak numbers of $>$500 murrelets per survey, we encountered enough murrelets to detect changes in juvenile/adult ratios; (we assumed a minimum of 2% juveniles, and to detect a change of 50% with 95% probability, at least 100 birds should be encountered).

Prince William Sound may be uniquely suited for development and application of a murrelet reproductive index because of its large murrelet population, its relatively compressed breeding season

(Hamer and Nelson 1995, Kuletz unpubl. data), and the apparent migration of adults from the area soon after breeding. Additionally, the foraging ranges of adults has been studied (Burns et al. 1994, Kuletz et al. 1995) and the total population has been, and will continue to be monitored regularly by a separate study.

Sub-Objective a: Timing and abundance of juveniles relative to adults

Data Collection.-- We will survey 6 sites to examine trends in the timing and abundance of juveniles. In late summer, adult murrelets at Naked Island were concentrated nearshore (Kuletz et al. 1994b). However, in Oregon and California, Beissinger (1995) found that because adults occurred offshore (>1 km) more than juveniles, the ratio of juveniles in nearshore water tends to be inflated 2 or 3 times that of the true local population. Ideally, surveys would be conducted nearshore and offshore to determine true juvenile ratios. However, to obtain a sample size adequate for examining seasonal and among-site variation, we will focus on habitat where juveniles concentrate. At 2 sites we will survey offshore transects as well as shoreline transects. If sufficient numbers of juvenile murrelets are found in the offshore regions, and the total number of adults fluctuates among years relative to pelagic or shoreline habitat, we will modify surveys to include more pelagic habitat.

Surveys will be conducted by 2 crews of 3 observers operating from 25 ft. vessels or 14 ft inflatables and using FWS protocol (Klosiewski and Laing 1994). Complete shoreline surveys (<200 m from shore) will be conducted at 6 sites, and randomly selected 2 km transects within 2 km of shore will be surveyed at two of these sites. The shoreline surveys will follow established FWS shoreline transects that are digitized on Atlas/GIS files (Strategic Mapping, Inc. 1992). The surveyed coastline will be approximately 50-60 km at each site, which in 1994, was the area that could be surveyed between 0600-1600 hours on the same day (murrelet counts vary significantly earlier or later in the day [Carter and Sealy 1990]).

The first surveys will be conducted in June to obtain a baseline adult murrelet population index. Juvenile surveys will be conducted at the same 6 locations between mid-July and late August twice weekly. Thus for baseline surveys, each site will be surveyed at least twice, for a total of 12 surveys. In the late summer surveys, the number of surveys will depend on the variability within and among sites surveyed in 1995; currently, each site is planned to have 10 surveys, for a total of 60 surveys.

The observers will count all birds $\leq$ 200 m from shore. Records for each transect (averaging 3 km) will be kept separate to allow for microhabitat classifications. Observers will be trained to score birds by plumage and behavioral characteristics using photos, study skins, drawings and on-sight training to standardize observers. In 1994 the percentage of unidentified black/white murrelets and juveniles were closely correlated by date, suggesting that many of the black/white birds were juveniles. Results from 1994 will be used to refine the data collection format. In 1995 and 1996 we will record more detailed data for each black/white bird, to improve our identification criteria: the quality of the observation, presence of an egg tooth, absence of white on the upper mandible, presence of a dusky breast band, dusky flecking on the flanks, percentage of white on the breast, back and flanks, missing or rounded primaries during a wing stretch, diving or flying behavior.

Data analysis. -- We will test for similar trends among sites in juvenile counts by graphing the frequency distribution of juveniles by date. If the null hypothesis that the seasonal distributions of numbers of juveniles does not differ among sites is not rejected, it will suggest that the chronology indicated by juvenile surveys is a reasonable measure of murrelet breeding activity throughout Prince William Sound. We will use power tests on the 1995 results to determine the probability of Type II errors.

We will also test for differences in the absolute numbers and ratios of juveniles among sites. For the 2-week peak in juvenile numbers for each site, the ratio of juveniles (average number counted each day, by site) will be calculated relative to total murrelets (average of 2 surveys per site) in June (presumably the local breeding population). The average number of juveniles per survey will also be used to derive an index relative to average number of adult murrelets during the same survey. We will use a 2 x 6 contingency table to test the hypothesis that there is no difference in juvenile ratios among sites. If the null hypothesis is rejected, we will use results from sub-objective b to determine if environmental features are related to local variation in productivity. In the long-term, we will compare trends in murrelet productivity and the total population estimates for Prince William Sound.

Sub-Objective b: Factors influencing the occurrence of juveniles

Data collection. -- For each transect we will record water depth and temperature, presence of freshwater runoff, glacial ice or kelp beds, sea conditions, precipitation, cloud cover, time and observed feeding activity. At 4 stations within each area, we will measure water clarity and surface salinity to obtain a daily average. We will calculate tide for each transect's start time with a Paradox (Borland, Inc. 1992) script (Kuletz / FWS files). The general bathymetry of the transect, the associated underwater and shoreline features, and the distance from shore of offshore transects will be obtained by GIS. We will also record other boat and low-flying activity during the transect. The relative abundance of forage fish (as determined by 96163), among sites and years, will be included as a variable.

Data analysis. -- We will combine data from 1995-1997 juvenile surveys to develop a descriptive model of influences on juvenile abundance. First, we will use parametric and nonparametric regression analysis to test the null hypothesis that juvenile abundance is not influenced by habitat or annual variation in marine conditions. The independent variables will include year, weather and sea conditions, time and tide, water depth and clarity, distance offshore, distance to underwater sill, shoreline type, bathymetric features (rocky, mud, plateau, shelf edge), presence of foraging flocks and relative fish abundance. Multivariate analysis will be used to determine what combination of factors best describe the variation in juvenile numbers. Based on previous studies, we predict that juvenile abundance will be positively related to freshwater runoff, protected coastlines, proximity to underwater sill or shelf edge and forage fish abundance. Juvenile numbers should be negatively correlated with water depth, distance offshore and boat traffic. There is insufficient data for the remaining variables to make predictions.

Sub-Objective c. Post fledging movement of juveniles

The ratio of adults to juveniles, and the validity of among-site comparisons, will be affected by the post-fledging movement of juveniles and adults, and perhaps their habitat preferences. Sub-Objective b will address the possible influence of habitat latter, and study 94102 addressed the foraging ranges of adults. In 1994 we radio-tagged a juvenile the day before it fledged from its nest. However, without tagging adults in 1996 it is unlikely we will have this opportunity. To determine the amount of juvenile movement within and away from a survey area, we will attempt to capture and radio-tag individual juveniles and track their movements during the survey period.

Data collection and analysis. -- We will attempt to capture 5 -10 juveniles on the water. We will begin trapping efforts once juveniles appear on the water and continue through August. Juveniles will be caught using spotlights and dipnets during darkness (Chris Iverson, pers. comm.). The capture efforts will concentrate in areas where we have frequently observed juveniles, such as Cabin and McPherson Bay on Naked Island, and the mouths of West and East Finger Inlets in Port Nellie Juan. Each juvenile will be measured and weighed and a 1.5g Holohil transmitter glued to its back. Picric acid will be put on the whites of the wings, neck and rump to facilitate visual observations from a distance. We will search for the juveniles during surveys and with spotting scopes from land when possible.

Although we will not know the juvenile's exact nest location or its fledging date, we will determine the average length of attendance in an area over time. The average distance covered over the length of observations (among all marked juveniles) will be used to adjust the design protocol.

C. Contracts and Other Agency Assistance

When possible, we will be refueling our survey vessels at Whittier or Valdez. However, to economize on gas and time, we will also contract a barge to deliver gas barrels for storage at sites in Prince William Sound.

Several camp locations will be necessary to cover all 6 areas on this tight schedule. Most of the areas are part of the Chugach National Forest, and permits will be obtained from the U.S. Forest Service for camp sites on Naked Island (shared with the pigeon guillemot portion of project 96163), Eleanor Island, (shared with the kittiwake portion of project 96163) and Port Nellie Juan. We will request temporary lodging and gas storage at the Unakwik Inlet and Main Bay hatcheries from the Prince William Sound Aquaculture Association. The Jackpot Bay location, which will be shared with the pigeon guillemot study, will be leased from Chenega Native Corporation.

We have the expertise and technical support to perform the majority of our geographic information system (GIS) needs. As coverages are developed for nearshore and pelagic areas of Prince William Sound by other projects, we may require agency support to obtain files. Our study could eventually integrate data on forage fish and oceanographic conditions obtained by NOAA and the PWS Systems Studies.

D. Location

The study sites will be Jack and Galena bays in Valdez Arm, Unakwik Inlet, Naked Island, northern Knight Island, central Port Nellie Juan, and Jackpot Bay/Dangerous Passage near Chenega Island (Fig. 1). Our boats will operate out of Whittier and Valdez, where we will rent dock space and purchase some supplies and services. On most days in the field, crews will camp at sites near survey areas.

SCHEDULE

A. Measurable Project Tasks for FY 96

Start up to April 14	Order radio tags, obtain capture and camping permits, begin hiring of personnel, arrange logistics.
April 15 - May 15	Hire personnel, safety training for field, purchase commodities.
May 16 - May 30	On-site training for at-sea surveys, establish field camps.
June 1 - June 15	Conduct baseline at-sea surveys.
June 16 - July 14	Data entry, purchase commodities, training on murrelet plumages.
July 15 - August 31	Conduct juvenile at-sea surveys, capture and follow tagged juveniles.
Sept.1 - October 31	Data entry, GIS analysis and analysis of field data.
Nov. 1 - Dec. 31	Data analysis and report writing.
April, 1997	Annual report on FY 96 data.

B. Project Milestones and Endpoints

FY 95	Collect data to address sub-objectives a and b
FY 96	Preliminary analysis of FY 95 field data
	Collect data to address sub-objectives a, b and c.
FY 97	Preliminary analysis of FY 96 field data
	Collect data to address sub-objectives a, b and c
FY 98	Final analysis of data from FY 95 - 97
	Final report addressing the primary objective

C. Project Reports

1996 - 1998	
December 15	Draft annual report submitted for internal review
February 15	Draft annual report submitted to Chief Scientist for peer review
April 15, 1996	Annual report with preliminary analysis on FY 95 data
April 15, 1997	Annual report with preliminary analysis of FY 96 data
April 15, 1998	Final report with analysis of data from 1995 - 1997

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will share logistical support in the use of barges, fuel storage and temporary camps with the Harlequin Duck project (96427) and the pigeon guillemot and kittiwake components of the APEX project (96163). This study will complement and benefit from the APEX project; project 96031 was designed to overlap the study areas surveyed by the APEX project so that we can eventually examine the hypothesis that food is limiting recovery of murrelets in Prince William Sound. The murrelet project could also benefit from information obtained through components of the PWS System Investigation related to forage fish (Isotope Tracers [95320I], Physical Oceanography [95320M], Nearshore Fish [95320N]). Project 96031 will use the total murrelet population estimates for Prince William Sound provided by the marine bird surveys (96159) to compare trends in juvenile abundance to trends in the total population.

ENVIRONMENTAL COMPLIANCE

Under DOI guidelines for the National Environmental Policy Act (NEPA) this project qualifies for a Categorical Exclusion.

OK'd by TC 8-25-95
Add'l $10,000 OK'd 12-11-95

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Rd.
Anchorage, Alaska 99503-6199

IN REPLY REFER TO:
21 July 1995

TO: Molly McCammon, Executive Director, Restoration Office

FROM: Kathy Kuletz, Principal Investigator of Marbled Murrelet Project

RE: Project 96031 / Development of a Productivity Index to Monitor the Reproductive Success of Marbled and Kittlitz's Murrelets in Prince William Sound, Alaska.

Dear Ms. McCammon:

Your letter of 29 June presented a preliminary recommendation to fund Project 96031 at the level of $60,000 in FY 96 to close out 1995 field work (95031) and synthesize previous murrelet studies sponsored by the Trustee Council. You also recommended that the Council defer a decision on possible murrelet surveys in FY 96 pending review of the Seabird/Forage Fish study (Project 96163, APEX) in Fall 1995. In the event that these decisions are not altered following public comment and final review by the Council, I submit this revised proposal for FY 96 funding of the Marbled Murrelet Restoration Project. Project 95031, currently underway, was originally funded for field work and write-up through March 1995.

Background

Monitoring the adult murrelet population can not determine if trends are the result of changes in murrelet productivity, because unusually high adult mortality may drive population trends. Seabirds are generally long-lived and low recruitment may not be manifest for a decade. Murrelets are the most abundant seabird in Prince William Sound (PWS) in the summer, yet we will not obtain information on their productivity unless we research and develop an index that allows for a reasonable sample size, is repeatable and reliable.

Project 95031, 'Reproductive Success as a Factor Affecting Recovery of Marbled Murrelets in Prince William Sound, Alaska,' was proposed and approved as the first year of a 3-year project to develop a productivity index for *Brachyramphus* murrelets (marbled and Kittlitz's murrelets). Secondarily, it proposed to examine the relationship between juvenile abundance and the seasonal, physical and biological environment, that would allow us to develop a descriptive model of where juveniles might be found and what elements correlate with their abundance. The model and productivity index would indicate what factors influence murrelet productivity in PWS, and thus suggest management options to promote murrelet recovery.

To derive an index of murrelet productivity I am using at-sea surveys to obtain absolute numbers of juvenile murrelets and their ratio to adults. Prince William Sound is well suited to this method because of the abundance and ecology of murrelets here (see Proposals 95031 and 96031 for details). Additionally, our information on the foraging ranges of adult murrelets and their chronology (Burns et al. 1994, Kuletz et al. 1994a, Kuletz et al. 1995), allow this project to use a comparative approach to examine sources of variability in juvenile abundance and seasonality.

Work in FY 95

Six study sites in PWS, each with 40-60 km of shoreline transects and 25 km of pelagic transects at two of the sites, were chosen for replicate surveys. These six areas were surveyed 4 times each in June during the murrelet incubation phase. The June surveys provided baseline murrelet abundance at each site, since abundance and distribution is more variable in late July and August, and may not reflect the local breeding population (Kuletz 1989, Kuletz et al. 1994b, Kuletz 1995). This portion of the field work has been successfully completed for 1995. Currently, two crews operating from boston whalers are beginning the second stage of surveys, from 17 July - 31 August. During this period, we will obtain 11 replicates at each site. Based on our 1994 pilot study, juveniles should peak in early August and remain high until the end of August.

Upon completion of field work, we will begin data entry, data compilation and digitizing of juvenile observations. The first stage of analysis will be a Geographic Information System (GIS) derivation of detailed bathymetric coverage, after which we will determine the proportions of categorical shoreline and bathymetric features for each transect, overlaid with murrelet abundance. In the second stage of analysis I will test for convergence among-sites by comparing abundance curves over time, the absolute numbers of juveniles and their ratio to adult counts both in June and in August. To examine habitat associations, multivariate analysis will be used to determine what factors best describe variation in juvenile numbers. Added to the environmental variables will be information on forage fish abundance and distribution obtained by the APEX and SEAS projects, as well as chick prey used at pigeon guillemot and kittiwake colonies (the seabird productivity portions of APEX).

The report for 95031 will include our results from the 1995 field season, as well as a discussion integrating results from murrelet projects 94102 and the at-sea portions of R15 and 93051B. The results would also be used to improve the study design of proposed work in FY 96 and FY 97. Depending on the statistical power of the tests in 1995, I may adjust survey effort. For example, based on large confidence intervals from the June 1995 surveys, additional pelagic transects were added for the July/August surveys. However, the density of

murrelets in the pelagic surveys was so low they may be eliminated in the future. Additionally, if specific environmental factors contribute significantly more to variation in murrelet numbers than other variables, they can be targeted for further study.

Close-out of 95031

Close-out costs for Project 95031 are primarily for personnel, including myself and a GIS technician/biologist. In addition, the Restoration Office requested that I write a synthesis of the murrelet projects. I propose to address this additional effort by publication of three articles in peer-reviewed professional journals. The articles will collectively represent the synthesis of the murrelet projects by presenting findings on nesting habitat, marine habitat use and foraging, and an overview of the restoration projects. The synthesis paper will distill the goals, accomplishments and primary findings of the *Exxon Valdez* murrelet restoration projects, and suggest future directions towards restoration. These publications offer the best way to present our work on murrelet restoration to the scientific community and the public.

My time thus has two components - closeout of 1995 work and the integration and synthesis of murrelet restoration projects to date. My estimated time for completion of the final report remains 30 March 1996. Additional time will be required for the publications, in particular the synthesis paper. I will work on the papers throughout the close-out phase concurrent with working on the report for 95031. However, depending on turnover time from reviewers, final manuscripts may require revision after May 1995.

Continuation of Reduced 96031

This project offers a unique opportunity to integrate murrelet data with the results of concurrent APEX studies on forage fish availability and the prey use and productivity of other seabirds in the same area. In addition, an independent population estimate for murrelets in PWS will be obtained in 1996 (Project 96159), providing background population trend data following the spill.

The murrelet project would be impaired by missing the 1996 field season completely. Three years is a minimum to determine if the abundance of juvenile murrelets correlates with, or is independent of, prey abundance or the productivity of other seabirds. Thus, our sites were selected to overlap the areas used by the APEX study. It is also best to have multiple years of data to evaluate variability in counts and the influence of annual environmental conditions. Therefore, I propose that pending review and funding of FY 96 field work for the APEX project in Fall 1995, a reduced scope of murrelet work be supported in 1996.

The reduced murrelet restoration work would likely follow the techniques and analyses presented in the 96031 proposal, depending on the results from 95031. However, we would concentrate our effort during peak juvenile occurrence, and emphasize sites that remain in the sampling schedule of the APEX project. This would still require two boats and crews, but surveys would only be conducted during approximately 3 weeks in August, and likely include only nearshore habitat. With this schedule, personnel and equipment savings would be realized by using boats provisioned for, and crews trained for, the July 1996 boat surveys (Project 96159). The GIS analysis of shoreline and bathymetric features will have been completed in 1995, and GIS requirements in 1996 would be reduced. Pending final approval of APEX plans for 1996, I will provide a detailed study proposal for a revised FY 96 project if requested.

Following is the budget for close-out of 95031 and a list of proposed publications. You may call me at (907)-786-3453 if you have any questions or comments, or fax to (907)-786-3641.

cc: Catherine Berg
David Irons
Stan Senner
Dr. Robert Spies

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Rd.
Anchorage, Alaska 99503-6199

IN REPLY REFER TO:
29 January 1996

Molly McCammon
Executive Director
Exxon Valdez Oil Spill Trustee Council Restoration Office
645 G Street, Suite 401
Anchorage, Alaska 99501-3451

Dear Molly,

Your office has requested a short memorandum and revised budget for Project 96031, Development of a Productivity Index to Monitor the Reproductive Success of Murrelets in Prince William Sound. Here I briefly describe the purpose of the additional $10,000 and minor changes to the memorandum dated 21 July 1995.

On recommendation of the Chief Scientist, future work on the marbled murrelet will be considered in the context of the APEX predator project (96163). The Trustee Council gave limited funding to facilitate integration of the murrelet project with APEX. The funds will be used for two months of my time, plus technician assistance. The attached budget has been revised to include the $10,000 funded to 96031 in FY96. I will use the additional funds to meet with APEX principal investigators, examine existing data to identify data needs, write a proposal for FY97 and submit it to the Trustee Council.

The time frame for FY97 proposals requires that the integration with APEX occur primarily between mid February and mid April. During this time, I will also be completing the final report for Project 95031 and working on publications. Because of the time that will be devoted to APEX meetings and reviews, my publication schedule will change slightly. Additionally, the federal furloughs have affected my schedule. I now anticipate that three proposed articles will be submitted to journals between April and September 1996. Thank you for your continued support.

Sincerely,

Kathy Kuletz
Principal Investigator

cc: Catherine Berg, DOI Liaison
Stan Senner, Science Coordinator

Publication of Seabird Restoration Workshop

Project Number:	96038
Restoration Category:	General Restoration
Proposer:	Pacific Seabird Group
Lead Trustee Agency:	U.S. Fish and Wildlife/DOI
Cooperating Agencies:	None
Duration:	1 year
Cost FY 96:	$22,700
Geographic Area:	No field work in this project
Injured Resource:	Common Murre, Harlequin Duck, Marbled Murrelet, Pigeon Guillemot

ABSTRACT

To further the emerging discipline of seabird restoration, the Pacific Seabird Group (PSG) is holding a workshop in September 1995. The workshop will bring together experts in seabird biology and restoration. It will include discussions of the theoretical and practical aspects of seabird restoration and provide recommendations to allow the establishment of restoration plans founded on the best available scientific information and opinion. This proposal seeks funds for the writing and publishing of manuscripts summarizing the workshop discussions.

INTRODUCTION

The *Exxon Valdez* Oil Spill (EVOS) in 1989 caused the mortality of an estimated 100,000 to 300,000 birds totaling 90 species (Piatt *et al.* 1990). Many seabird species suffered only minor mortalities while others that had many individuals die apparently did not suffer population level impacts. In 1992 six species had not yet recovered from the effects of the spill. These were the Bald Eagle, Black Oystercatcher, Harlequin Duck, Common Murre, Pigeon Guillemot and Marbled Murrelet. By 1993 the Bald Eagle and Black Oystercatcher were considered to have recovered. (Draft EVOS Restoration Plan, 1993). In addition the status of other seabird species is currently being considered by the EVOS Trustees: Kittlitz's Murrelet, Black-legged Kittiwake, Common and Yellow-billed Loons, cormorants, Arctic Terns and Scoters.

Seabird restoration as discipline is in its infancy and represents a new approach to seabirds. Over the past twenty years seabird biologists have conducted studies on the natural and anthropogenic factors that can contribute to fluctuations in numbers or effect productivity. Seabird managers working for agencies have been primarily concerned with cataloguing and maintaining populations. Only recently have scientists and managers had to decide how best to spend restoration funds in the wake of an oil spill or other pollution event believed to have affected seabird populations.

To address this problem the Pacific Seabird Group will hold a workshop of recognized experts in seabird biology and management to discuss the current state of seabird restoration. The workshop is being held in Alaska in late September 1995 and, through plenary sessions and small group discussions, will allow the attendees to address the theoretical and practical basis for seabird restoration plans. The workshop will produce:

1) A summary of the type of baseline data needed to develop effective restoration plans and a listing of the information needed to develop restoration plans for the species that have still not recovered from the EVOS.
2) A summary of the type of post-spill research and monitoring that needs to be conducted to assess the degree and reasons for the state of recovery.
3) A summary of known restoration techniques (what is included in the EVOS categories of general restoration and habitat acquisition) and an evaluation of these techniques for the EVOS seabirds that have yet to recover.
4) A list of untested techniques judged to have enough potential that further research is warranted.

As of late April the selection of 25 attendees is nearly complete and a list of subgroup discussion topics has been developed. Principal subgroup topics are:

Pre-spill baseline data sets
Damage assessment and post-spill monitoring
Restoration techniques
Seabird population biology

Additional topics and detailed items to be addressed by each subgroup will be developed in the next two months.

NEED FOR THE PROJECT

A. Statement of Problem

Some seabird species affected by the *Exxon Valdez* Oil Spill have failed to attain pre-spill population levels. Little discussion has occurred on how funds allocated to restore seabird populations can best be spent. Much of the work done in restoration ecology has addressed restoration of habitats that are not expected to recover without human assistance or direct restoration of species that have declined to the point where recovery without human intervention appears doubtful. Most seabirds, however, have populations that naturally fluctuate and natural recovery from major declines caused by episodic natural or anthropogenic effects is common. The ability to recover naturally has complicated the development of seabird restoration plans since for restoration activities to be effective they must substantially increase the rate of recovery over what would occur naturally. Additionally much of the discussion of restoration options that has occurred has been conducted in a litigious setting where an unbiased scientific examination of hypotheses and theories may not be possible.

B. Rationale

To provide for the first open scientific discussion of seabird restoration the Pacific Seabird Group is holding a seabird restoration workshop in FY 95 to bring together recognized experts on seabirds, marine ecology, and restoration to examine seabird restoration needs and options. The current proposal seeks to continue this examination after the workshop through the preparation of manuscripts on the discussions that occurred at the workshop and topics identified by workshop participants as being of sufficient importance to warrant additional attention and review articles. In the months following the workshop PSG will solicit information and opinions from seabird biologists and managers who were not able to attend the workshop but whose information and opinions will enhance the final publication. Additionally, by publishing the results of the workshop, information on the current state of seabird restoration will be available to a larger audience.

C. Summary of Major Hypotheses and Objectives

Development and implementation of seabird restoration plans have suffered from a lack of discussion of the practical and theoretical issues relating to seabird restoration. The seabird restoration workshop being held in September 1995 will address many issues in need of consideration by trustee councils. The Pacific Seabird Group believes that major progress can be made through the convening of a workshop on seabird restoration and publication of the workshop discussions.

D. Completion Date

It is anticipated that the manuscripts generated by this work will be accepted for publication during FY 96.

COMMUNITY INVOLVEMENT

The publication of the results of the seabird restoration workshop will provide the first attempt to define and discuss seabird restoration. It will provide the public, a document that will discuss in detail the types of baseline and post-spill monitoring needed to develop restoration plans and the current restoration techniques available to seabird managers. This information should be of interest to those communities and organizations in the spill area concerned attempting to understand the recovery of spill-impacted species.

PROJECT DESIGN

A. Objectives

1. To allow input from experts not able to attend the 1995 Seabird Restoration Workshop.

2. To allow completion of manuscripts summarizing the results of the 1995 Seabird Restoration Workshop.

3. To publish a book containing the "white papers" and summaries of discussions from the 1995 Seabird Restoration Workshop.

B. Methods

Papers presented at the Pacific Seabird Group's 1995 Seabird Restoration Workshop, summaries of small group discussions and some papers written after the workshop will be published in a book or professional scientific journal. These papers will include summaries of relevant literature and the information and opinions from recognized experts in seabird biology and restoration.

C. Contracts and Other Agency Assistance

All work will be done by contract with contracts being awarded by a steering committee composed of PSG officers. Selection of persons receiving contracts will be done through the solicitation of proposals or through recognition of individuals who are in a unique position to write an article. U.S. Fish and Wildlife biologists will be asked to provide summaries of damage assessment and previous restoration activities.

D. Location

The workshop will be held in Girdwood, Alaska in September-October 1995. Manuscript preparation and editing will take place at offices of the authors, editors and PSG.

SCHEDULE

A. Measurable Projects Tasks for FY 96

September 29 - October 2	Seabird Restoration Workshop at Alyeska
November 1	Drafts of workshop discussions submitted
November - December	White papers and workshop discussion papers circulated to experts unable to attend the workshop
November - March	Preparation of review articles based on recommendations of workshop attendees
January-March	White papers and workshop discussion papers revised by authors based on information and opinions from reviewers
July	Final drafts of white papers, workshop discussions and review articles submitted to editors for publication in articles in a journal or chapters in a book.

B. Project Milestones and Endpoints

Manuscripts on subgroup discussions, post-meeting discussion and literature review will be completed on the following schedule:

November 1	Drafts of workshop discussions submitted and sent out for review by discussion group members and outside reviewers
January 1	Review of draft manuscripts completed March 1 - Final draft of manuscripts submitted to technical editor
July 1	Technical editor completes editing of manuscripts and submits articles to a publisher.

Schedule of publication after manuscript submission will be determined by the publisher.

C. Project Reports

November 1	Draft report of the workshop (funded with FY 95 funds) will be submitted on November 1 and complete the work done with FY 95 funds
April 15	Progress report including recent drafts of all articles being prepared for publication and information on the proposed publication outlet

Another report will be submitted when a publisher has been found, including details of the publishing arrangements. The final report will be submitted when after publication.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Organizers of the seabird restoration workshop have discussed its objectives and format with U.S. Fish and Wildlife Service and non-agency biologists conducting the recovery of seabirds from the *Exxon Valdez* oil spill. This has included conversations with investigators from the following Trustee Council funded projects:

94039	Common Murre Population Monitoring	DOI-USFWS
94066	Harlequin Duck Recovery Monitoring	ADF&G
95159	Marine Bird and Sea Otter Boat Surveys	DOI-USFWS
94506	Pigeon Guillemot Recovery	DOI-USFWS

Additionally scientists contracted with Exxon have been consulted regarding their views on to how best to frame the discussion of restoration options. The implementation of restoration plans is the responsibility of a trustee council, however, the gathering of baseline data that is essential to the development of restoration plans is the responsibility of normal agency management. The guidelines that will be generated by the workshop will examine the nature and quantity of baseline data that should be gathered through normal agency management activities.

ENVIRONMENTAL COMPLIANCE

Not applicable.

FAX'd → Spies 11/8/95

Monitoring of Cutthroat Trout and Dolly Varden Habitat Improvement Structures

Project Number:	96043 - B Revised 11/7/95
Restoration Category:	Monitoring
Proposer:	USFS
Lead Trustee Agency:	USFS
Cooperative Agencies:	None
Duration:	5 Years
Cost FY 96:	$29,600
Cost FY 97:	$24,000
Cost FY 98:	$24,000
Cost FY 99:	$26,000
Geography Area:	Western Prince Williams Sound
Injured Resource / Service	Cutthroat Trout and Dolly Varden

ABSTRACT

This project provides for monitoring of habitat improvement structures and their effects on cutthroat trout and Dolly Varden populations. These structures were installed in 1995 under EVOS Restoration Project number 95043B. There has been concern raised that habitat structures may inadvertently increase coho salmon populations, and thereby increase competition stress on dolly varden, and cutthroat trout populations. This monitoring will seek to address those concerns, and questions.

INTRODUCTION

In 1989 the oil tanker *Exxon Valdez* ran aground on Bligh Reef spilling millions of gallons of crude oil into Prince William Sound (PWS). The ensuing oil spill damage assessment identified oil spill related injuries to the cutthroat trout (*Onchorhynchus clarki*) and Dolly Varden char (*Salvelinus malma*) populations among other species in PWS. Information collected in 1989-1991 by the Natural Resources Damage Assessment (NRDA) studies documented lower growth rates for cutthroat trout and Dolly Varden char in oiled areas than in unoiled areas. The reduced growth rates persisted into 1991 when studies were discontinued. It is unknown if growth rates have since returned to normal. Mortality rates for sea-run Dolly Varden char in oiled areas were significantly higher than rates from sites in the non-

oiled areas of eastern PWS (EVOS Trustee Council, 1994).

Cutthroat trout in PWS are at the northern extent of the species' North American range. Generally speaking, species inhabiting the extreme limits of their habitat exhibit higher sensitivities to environmental stresses than the same species well within the habitat limits. Little is known of the genetic diversity, distribution, or life histories of cutthroat trout in PWS. The cutthroat trout stocks known to exist within PWS are few in number. The Otter Creek population, as well as others, appear to be discrete populations with limited interbreeding with other cutthroat stocks. It is highly possible that there have been unique genetic adaptations in these populations due to local conditions and their relative isolation from other stocks. The population in a given stream system rarely number more than 1,000 individuals. Several stocks of cutthroats within PWS appear to be anadromous and have a limited home range within streams (Heggenes et al., 1991). The number of streams within PWS that have cutthroat trout populations is unknown. Of 143 streams surveyed for spawning salmon in 1989, anadromous cutthroat trout were found in only 10 streams. Both adults and subadults of anadromous populations migrate to the ocean for summer feeding (Trotter, 1989; Hepler et al, 1993). Emigration to saltwater occurs in early May through July (Hepler et al, 1993). They return to freshwater in July through November, peaking in September and October (Trotter 1989; Wedemeyer 1993). In Prince William Sound, field observations indicate cutthroat are spring spawners.

Sampling by Glacier Fisheries Crews in 1994 indicated that cutthroat trout densities were greatest in the medium gradient tributary stream to Otter Lake and in the upper reaches of Otter Creek. This is consistent with studies that have shown that cutthroat trout juveniles are pushed to less desirable habitats by the more dominant coho salmon juveniles (Glova and Mason, 1976). Interspecific competition with juvenile coho salmon limits cutthroat trout production. Quality pool rearing habitat is a key factor in cutthroat trout production.

During the 1995 field season Glacier Ranger District crews installed habitat improvement structures at Otter Lake, Gunboat Lakes, Red Creek and Billy's Hole to improve cutthroat trout and Dolly Varden habitat in PWS. These structures were installed under EVOS Restoration Project Number 95043B. The distribution and densities of cutthroat trout, Dolly Varden and coho salmon would be monitored at these locations using standard mark recapture techniques and snorkel surveys. If suitable control streams can be located they would also be monitored. Instream structures installed in 1995 would also be monitored. The existing habitat that may be effected by the structures would be physically measured and microhabitats classified accordingly on an annual basis for comparison. Monitoring would commence on an annual basis and continue for four years.

NEED FOR THE PROJECT

A. Statement of Problem

Limited information is available on the genetic diversity, distribution, competitive interactions or general life histories of cutthroat trout in PWS. In addition, there is concern that habitat enhancement structures may inadvertently increase coho salmon populations, thereby; increasing competitive stress on cutthroat trout populations.

B. Rationale

Additional information on cutthroat trout distribution, habitat utilization and competitive interaction with juvenile coho in PWS will assist managers in making future decisions that may affect cutthroat trout.

Monitoring prior to and after the installation of improvement structures will provide necessary information to ascertain the effectiveness of the various projects or of a particular structure.

C. Summary of Major Hypotheses and Objectives

The number of cutthroat trout at the project locations will increase due to the habitat improvements made in 1995.

Cutthroat trout densities will be greater at habitat improvement sites, than at similar adjacent habitats having no improvement structures.

This projects objectives are to determine the relative abundance and distribution of cutthroat trout and juvenile coho salmon after improvement structure installation and the effectiveness of the habitat improvements made in 1995 for a period of one life cycle of coho salmon.

D. Completion Date

Baseline data will be collected prior to any habitat improvement work in 1995. Data to meet the project objective will be collected in 1996, 97, 98, with a final field survey and project completion report in 1999.

COMMUNITY INVOLVEMENT

On January 20, 1994 letters were mailed to 156 individuals, agencies and organizations requesting comments on the proposed habitat enhancement for cutthroat trout in Otter Creek that this proposal is designed to monitor.

In January of 1994, the "Chugach National Forest Schedule of Proposed Actions for Environmental Analysis" was mailed to more than 600 individuals, agencies and organizations. This document has since been mailed on a quarterly basis. The mailings included the Otter Creek project and a contact person for additional information concerning the project.

PROJECT DESIGN

A. Objectives

The objective of this project in general is to monitor and document the response of cutthroat trout to modifications made to their environment.

Specific objectives are:

1. Measure abundance and distribution of cutthroat trout and juvenile coho in the proposed project locations for the period specified.

2. Measure and monitor cutthroat and juvenile coho utilization of newly installed habitat improvements.

3. Measure and monitor the effects that structures have on adjacent aquatic microhabitats.

4. Provide annual project reports on the proposed project.

5. Provide a project completion report and a summary of our findings on the effectiveness of the habitat structures installed in 95.

B. Methods

The major hypotheses for this project states that the number of cutthroat trout at the project locations will increase due to the habitat improvements made in 1995. To test this hypotheses and meet the projects objectives five working hypotheses have been developed.

Working Hypotheses:

Hypotheses 1. The abundance of cutthroat trout at the project sites will increase over the project duration.

Hypotheses 2. The current distribution of cutthroat trout within the project area will change over the duration of the project.

Hypotheses 3. Cutthroat trout will be the predominant species to utilize the newly created habitat structures.

Hypotheses 4. Aquatic microhabitats adjacent to areas of improvement will be affected by the structures installed in 1995.

Hypotheses 5. The structures installed in 1995 benefited cutthroat trout at those project locations.

To test hypotheses number one through three, baseline data on the relative abundance, distribution and habitat utilization of cutthroat trout at the project locations were collected during the 1995 field season and are proposed to be collected on an annual basis there after for the project duration.

Cutthroat abundance will be estimated using a method described in Hankin's (1986) report, Sampling Designs for Estimating the Total Number of Fish in Small Streams. The specific method will be of a two stage stratified random sampling design utilizing auxiliary variables to bias estimators. This method is described in detail as Design B: Ratio Estimation in Hankin's report. The technique for population estimation in each primary unit will be the mark-recapture method known as the Petersen Index using Bailey's (1951) formula to correct for bias. Collection will be conducted using baited minnow traps and fish will be marked by caudal punches. Project area streams will be surveyed and habitats classified using the Hankin and Reeves (1988) methodology.

Stream habitat surveys were conducted during the early part of the 1995 field season in conjunction with the installation of the improvement structures. Data collected from the surveys are being analyzed and the associated habitat units characterized. Primary units (those to be sampled) will then be selected by stratified random sampling. The strata will consist of various size pools, riffles, glides and any other habitat type suspected to be closely associated with cutthroat trout.

Once primary units have been selected population estimations will be made using the method described earlier. These estimations should be done in mid to late summer to minimize bias due to seasonal migration of 1+ fish within the stream, estimations will focus on this age class of fish. The selected primary units will become the permanent trapping sites for population estimations in subsequent years. Annual population estimates of the primary units for the project duration should provide enough information to detect a change in the relative abundance and distribution of 1+ cutthroat trout at the project sites.

Structures and their effects on adjacent habitat types will also be monitored by physical measurements and habitat classification. Additionally an annual photographic record of each structure will be established and maintained over the project duration.

Hankin in his (1986) report discusses errors of estimation of the total number of fish in a stream arising from two sources: (1) extrapolation from the small number of sampled sections to the entire stream, and (2) errors of estimated fish numbers within sampled sections. Hankin demonstrated that errors arising from the first source will usually be far grater than those from the second source, and that total errors of estimation can be reduced by making sampled sections equivalent to natural habitat units. By stratifying these habitat units and selecting sampling units randomly the precision of estimators can be improved and information on the distribution of cutthroat trout within the stream can be gathered.

Mark-recapture population estimates for primary units utilizing minnow trapping techniques will lead to errors in estimated fish numbers for sampled sections due to size selectivity and inefficiency of minnow traps to capture all individuals within a population. There is however a correlation between the sampled catch and the true population for a given size of individuals within a population. This is discussed in a 1976 paper by Arthur M. Bloom, Evaluation of Minnow Traps for Estimating Populations of Juvenile

Coho Salmon and Dolly Varden. Cutthroat trout of 1+ age class fall within this size range. Though electrofishing is a more efficient means of sampling stream fish populations, currently ADF&G restricts the use of electrofishing in streams containing trout. We concur that it would not be wise to use electofishing when working with a potentially threatened resource.

C. Contracts and Other Agency Assistance

This project will be implemented by the U.S. Forest Service no contracts are expected at this time.

D. Location

Monitoring will occur at the project sites listed for the Cutthroat Trout / Dolly Varden Habitat Improvement Project, number 95043B.

Otter Creek, Bay of Isle, Night Island, PWS.
Gunboat Creek, Eshamy Bay, Western PWS.
Red Creek, Esther Passage, PWS.
Billy's Hole, Long Bay, Northern PWS.

SCHEDULE

A. Measurable Project Task for FY 96

Dec 15 (1995): Report on preliminary finds of population and distribution estimations.
Aug 12 - Aug 31 (1996): Inspect and measure effects of installed structures. Conduct population estimates of primary units.

B. Project Milestones and Endpoints

Dec 15 (1995): Project completion report on project number 95043B. Objective (4) completed.
Aug 12 - Aug 31 (1996): Inspect and measure effects of installed structures. Conduct population estimates of primary units.
Dec 15 (1997): Report on preliminary findings of population and distribution estimations. Objectives (1, 2, 3) partially completed. Objective (5) completed.
August (1997): Inspect and measure effects of installed structures. Conduct population estimates of primary units.
Dec 15 (1998): Report on preliminary findings of population and distribution estimations. Objectives (1, 2, 3) partially completed. Objective (5) completed.
August (1998): Inspect and measure effects of installed structures. Conduct population estimates of primary units.
Dec 15 (1999): Report on preliminary findings of population and distribution estimations. Objectives (1, 2, 3) partially completed. Objective (5) completed.
August (1999): Inspect and measure effects of installed structures. Conduct population estimates of primary units.

April 15 (2000): Provide a final report for peer review summarizing project results. This will satisfy objectives (1, 2, 3, 6).

C. Project Reports

Dec 15 (1995): Project completion report on project number 95043B.
Dec 15 (1996): Report on findings of population and distribution estimations.
Dec 15 (1997): Report on findings of population and distribution estimations.
Dec 15 (1998): Report on findings of population and distribution estimations.
Dec 15 (1999): Provide a final report for peer review summarizing project results.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The proposed project is an integration of project number 95043B, Cutthroat Trout and Dolly Varden Habitat Restoration in PWS. This project is designed to monitor the long term effects of implementing project number 95043B. The proposal is a response from a primary land and resource manager (Forest Service) in Prince William Sound to the effects of the *Exxon Valdez* oil spill. The Forest Service has focused on this species as a result of the injury incurred from the oil spill. The proposal is not part of the normal Forest outyear planning program, therefore no funds have been directed towards this project within the Forest Service budgeting process.

ENVIRONMENTAL COMPLIANCE

All NEPA requirements have been satisfied to implement this project. The monitoring activities listed in this proposal were outlined in two EA's currently under review. The EA's mentioned are: Otter Creek Cutthroat Trout Habitat Improvement Project and Gunboat, Billy's Hole and Red Creek Cutthroat Trout Habitat Improvement Project. The Glacier Ranger District annually applies for and receives a Fish Resource Permit (Scientific Collections) from the Alaska Department of Fish and Game. The project locations are listed on that permit.

Historical Analysis of Sockeye Salmon Growth Among Populations Affected by Overescapement in 1989

Submitted Under the BAA

Announcement No. 52ABNF500082

1 May 1995

Project Number:	96048-BAA
Restoration Category:	Monitoring and Research
Proposer:	Dr. Gregory T. Ruggerone Natural Resources Consultants, Inc.
	Dr. Donald E. Rogers Fisheries Research Institute University of Washington
Lead Agency:	NOAA
Duration:	October 1 1995 to September 1 1996
Cost FY 96:	$116,900
Geographic Area:	Kenai River, Akalura Lake, Red Lake, Coghill Lake, Chignik Lake, Kasilof River
Injured Resource:	Sockeye salmon from Cook Inlet, Kodiak Island, Prince William Sound, and Chignik

ABSTRACT

Overescapement of sockeye salmon in several areas of Alaska occurred in 1989 as a results of the *Exxon Valdez* oil spill. Overescapement appears to have reduced salmon growth, leading to reduced survival. However, few records of sockeye growth in these systems occurred before 1989. We propose to use adult sockeye scales to reconstruct the growth of sockeye salmon before, during, and after the oil spill event. These data will be used to document the effects of the spill and the subsequent recovery of the sockeye stocks.

INTRODUCTION

The Exxon Valdez Oil Spill Trustee Council (EVOSTC) has identified several sockeye salmon stocks that were influenced by 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; the effect of overescapement in Chignik Lake on adult production will not be known until summer 1995, the year when the dominant age group (i.e., age 2.3) of the 1989 brood year return.

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. (1993) 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 (Ruggerone 1993).

Presently, the EVOSTC and the Alaska Department of Fish and Game (ADF&G) 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 may have been reduced when migrating through oiled waters, especially in Prince William Sound. This effect has been documented for pink salmon (Willette et al. 1993). To our knowledge, the early marine growth of sockeye salmon from the areas affected by the *Exxon Valdez* oil spill has not been examined.

Measurements of adult sockeye salmon scales offer a relatively inexpensive means to evaluate the effect on sockeye salmon growth of overescapement in freshwater and oil in

the marine environment. 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 (Henderson and Cass 1991, Zimmermann 1991, Bumgarner 1993, Ruggerone 1994) and the ocean (Rogers and Ruggerone 1993).

NEED FOR THE PROJECT

A. Statement of Problem

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 on sockeye salmon growth 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 (1993) demonstrated that growth of pink salmon in Prince William Sound was reduced.

B. Rationale

Analysis of sockeye salmon growth, based on adult scale measurements, is needed because 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 (D. Waltemyer, ADF&G, pers. comm.). 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 (see Rogers and Ruggerone 1993). 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.

C. Summary of Major Hypotheses and Objectives

Objectives:

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)

2. Measure annual growth zones of sockeye salmon from systems less affected by the oil spill (Kasilof River, Crescent Lake, Black Lake, and the Wood River Lake system)

3. Compare trends in annual growth zone measurements of sockeye from systems affected by overescapement or oil in the marine environment with that of sockeye not affected

4. 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.

Hypotheses:

1. Overescapement significantly reduced the growth of sockeye salmon

2. Migration of sockeye salmon through marine waters contaminated with oil caused reduced growth

D. Completion Date

A final report will be completed by 30 September 1996.

PROJECT DESIGN

A. Objectives

1. Measure annual and seasonal 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)

2. Measure annual and seasonal growth zones of sockeye salmon from systems less affected by the oil spill (Kasilof River, Crescent Lake, Black Lake, and the Wood River Lake system)

3. Compare trends in growth zone measurements of sockeye from systems affected by overescapement or oil in the marine environment with that of sockeye not affected

4. 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.

B. Methods

Adult sockeye salmon scales will be obtained from ADF&G for each population described above. ADF&G 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 (D. Waltemyer, B. Barrett, ADF&G, pers. comm.). 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 to be updated for these stocks.

At least 100 scales from the dominant age groups of each stock will be measured for each year. This sample size was determined to be adequate by Zimmermann (1991). The scales will be measured by the Optical Pattern Recognition System (OPRS) at Dr. Donald E. Rogers' scale laboratory at the University of Washington. The scale measurement methodology will follow that described by Zimmermann (1991), 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. For example, we will statistically test whether salmon growth in freshwater and in the first year at sea was significantly reduced by overescapement or the presence of oil in the marine environment.

Scales available through 1995 will be measured, analyzed, and reported during FY96. Scales collected during 1995 represent the last progeny of the 1989 brood year. Scales collected during 1996 and 1997 represent progeny of sockeye spawning after the spill. These scales would also be measured. 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. We plan to publish the results of the investigation in a peer-reviewed journal.

C. Location

The geographical areas that will be investigated include the Kenai and Kasilof River systems in Cook Inlet, Red Lake and Akalura Lake on Kodiak Island, Coghill Lake in Prince William Sound, and Chignik Lake on the Alaska Peninsula.

SCHEDULE

A. Project Tasks for FY96

October 1 - November 15:	Collect and press scales, if needed.
November 15 - 31 January:	Age scales and select scales for measurement
December 1 - July 31:	Measure scales
August 1 - August 30:	Analyze data
September 1 - 30 September:	Prepare report

B. Project Milestones and Endpoints

September 1996:	Effects of overescapement on sockeye growth
December 1997:	Growth during recovery period (measurements of scales from 1996 and 1997)

C. Project Reports

The primary analysis and report preparation will be completed during FY96. An update report will be prepared after measurements have been made of adults returning in 1996 and 1997. We anticipate that a final report would be prepared by December 1997. We plan to publish the results of the investigation in a peer-reviewed journal.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The ADF&G will provide sockeye scales for each of the stocks described above. These scales were collected as part of the ADF&G'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.

ENVIRONMENTAL COMPLIANCE

This project is not a field investigation. No specific environmental laws and regulations apply.

96052A

8/25/95 version

Project Title: Community Involvement/Traditional Ecological Knowledge

Project Number:	96052
Restoration Category:	General Restoration
Proposer:	Chugach Regional Resources Commission
Lead Trustee Agency:	Alaska Department of Fish and Game
Cooperating Agencies:	None
Duration:	7 years
Cost FY 96:	261,000
Cost FY 97:	250,000
Cost FY 98:	250,000
Cost FY 99:	250,000
Cost FY 00:	250,000
Cost FY 01:	250,000
Cost FY 02:	250,000
Geographic Area:	Oil spill area
Injured Resource/Service:	All Injured Resources/Services

ABSTRACT

Project 96052 would continue and expand on the original concept of increasing community involvement in the restoration process begun under 95052. This project would have two major components: community involvement and traditional ecological knowledge. Under the community involvement component a spill area-wide coordinator would be hired through a contract with Chugach Regional Resources Commission (CRRC) to serve as a liaison between the communities, and the existing network of scientists, agency personnel, restoration office personnel and the Trustee Council. Through direct communications with a network of local facilitators the spill area-wide coordinator, would actively involve local residents in the restoration program, particularly on-going scientific studies. The second project component, Traditional Ecological Knowledge (TEK), would consist of pilot a effort with the potential to integrate western science and local traditional knowledge to further the Trustees Council's restoration program.

INTRODUCTION

This project was initiated in 1995 as 95052 . Three local facilitators have been hired through cooperative agreements with the village councils of Tatitlek, Chenega Bay and Port Graham. Under 96052 the number of community facilitators would be expanded to include the communities of Nanwalek, Cordova, Seward, Valdez, Kodiak region, and Alaska Peninsula region.

Through a contract with CRRC a full-time, spill-area-wide coordinator, working out of the Restoration Office would be hired to accomplish the following tasks:

Community Involvement Component:

1. Increase involvement of community members throughout the spill region in restoration projects (local hire, use of local equipment, etc.). This would require becoming familiar with projects funded by the Trustee Council. identifying those that that would benefit by a community component, and working with Principal Investigators (PIs) to develop and implement.

2. Subcontract with and serve as contact point for community facilitators in each of nine participating communities (Tatitlek, Chenega, Port Graham, Nanwalek, Cordova, Seward, Valdez, Kodiak region, Alaska Peninsula region). Spill area-wide coordinator tasks would include:

    a. Assisting communities in the development of new project ideas, and working with Trustee Council staff and agencies to develop project proposals.

    b. Coordinating participation of community liaisons in annual Restoration Workshop and other workshops/meetings.

    c. Distributing a brief report/update twice-monthly to each community liaison, via regional computer network bulletin board service. Update could include information, on research proposals. study results, restoration work planned in the area, Restoration Office activities, Trustee Council actions, etc.

3. Organize the annual round of Trustee Council/Restoration Office meetings held in conjunction with Invitation/Draft Work plan. This would include presentations in certain communities by select PIs.

4. Work with community members and PIs to develop protocols for community visits by PIs.

5. Provide input at the Restoration Work Force meetings.

6. Provide input to the newsletter (Restoration Update) editorial board.

7. Prepare quarterly project status reports and coordinate annual/final reports.

Traditional Ecological Knowledge Component:
Under a Cooperative Agreement to be ~~developed and entered~~ into by ADF&G and CRRC, the Subsistence Division and the spill area-wide coordinator, along with other CRRC staff and in consultation with the communities, would jointly:

1. Develop guidelines, procedures, and protocols for the systematic collection and analysis of TEK. This would be done in consultation with the tribal councils and with the Chief Scientist to ensure data is collected in a manner that allows EVOS researchers to integrate it into their restoration projects.

2. Identify suites of injured resources that could be incorporated into the TEK approach in FY 96. This would also be done in consultation with the Chief Scientist.

3. Train the Community Facilitators in the collection of TEK, and supervise the collection of TEK.

4. Develop a database for management of TEK, and protocols for the use of the database. The database should be integrated with other similar databases, so that it can be made available to all Trustee Council agencies and scientists, local communities and regional Native organizations, and other user groups.

5. Provide training for and assistance to EVOS researchers/scientists on the interpretation and potential application of TEK to their restoration projects. This might include a special session at the Annual Restoration Workshop, a separate workshop at a different date, and/or ongoing involvement with select researchers.

6. Coordinate these efforts with other ongoing TEK efforts (e.g., Project 96244/Harbor Seals).

The specific tasks the local facilitators are expected to undertake include the following:

Community Involvement Component:

1. Inform the spill area-wide coordinator of community Issues/ concerns/questions. Issues could be identified through community meetings conducted by the community facilitators or through other means, and could include ideas for new projects.

2. Assist the spill area-wide coordinator in increasing community involvement in restoration projects. Tasks might include identification of community members with available boats and other equipment; who's available to work and what their skills are; assisting in local coordination of the annual round of Trustee Council community meetings as well as community visits from project PIs; etc.

3. Disseminate to community members the twice-monthly update from the spill area-wide coordinator.

4. Attend annual Restoration Workshop and certain scientific review sessions (on SEA, persisting oil, marine mammal projects, etc.).

Traditional ecological knowledge components

1. Assist in defining protocols for the collection and use of TEK.

2. Assist in identifying injured species on which TEK should be collected.

3. Receive training in the collection of TEK

4. Collect TEK under the supervision of the spill area-wide coordinator and Subsistence Division.

Subsistence Division/ADF&G would enter into a Cooperative Agreement with CRRC to facilitate cooperation on the project on the tasks previously identified on the previous page. In addition, ADF&G would:

1. Serve as contact point for community assistants trained under 95279 (food safety testing) to handle samples of abnormal resources, facilitate processing of samples, and communicate findings back to communities.

2. Provide technical expertise and general assistance to the Restoration Office, Trustee Council, spill area-wide coordinator, and PIs on subsistence restoration, including assistance in development of project proposals.

3. Prepare monthly reports for the Trustee Council Executive Director summarizing interactions by Subsistence Division staff with the public an oil spill restoration topics.

NEED FOR THE PROJECT

A. Statement of Problem

The *Exxon Valdez* oil spill caused severe disruption of the lives of many people living in the spill impact area. The spill also caused residents of the area to be concerned about the safety of their wild food sources, and the integrity of the surrounding natural environment. While scientific studies aimed at restoring the resources and services damaged by the oil spill have occurred throughout the spill -area, most of the researchers work for agencies or institutions based in Anchorage, Fairbanks, or outside Alaska. Residents have voiced concern over a lack of involvement by spill area communities in the restoration efforts, and incomplete communication to spill area inhabitants of study proposals and results. At the same time, 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.

B. Rationale

People living in the spill area have detailed knowledge about the condition of resources, which can significantly add to data collected as part of scientific studies, and possibly even enhance the success of restoration efforts. Local people have expressed a desire to be involved in all aspects of restoration projects, and a willingness to work with researchers.

This project furthers the Trustee Council's goal of facilitating the involvement of spill area residents and resource users in the restoration process.

C. Summary of Major Hypotheses and Objectives

The objectives of the project will be to:

1. Increase the involvement of spill area communities in the restoration efforts of the Trustee Council, and

2. Improve the communication of findings and results of restoration efforts to spill area inhabitants and the appropriate regional organizations. It is expected that by so doing, this project will increase the effectiveness of over-all restoration efforts.

3. Integrate western science and local traditional knowledge with the intent of furthering the Trustee Council's restoration program in a way that is sensitive to the needs of the affected communities.

D. Completion Date

Since the objective of this project is to integrate the local communities into the restoration program we see a need to continue this program until spill restoration is complete. The project should be evaluated on a yearly basis to determine how it can best serve the needs of the Trustee Council and the local communities.

COMMUNITY INVOLVEMENT

The core of this project is community involvement.

PROJECT DESIGN

A. Objectives

1. To increase the involvement of spill area communities in the restoration efforts of the Trustee Council.

2. To improve the communication of findings and results of restoration efforts to spill area inhabitants and the appropriate regional organizations.

3. To improve the communication of traditional ecological knowledge from local residents to scientists, which can significantly enhance the value of Trustee Council restoration efforts.

B. Methods

The project will be implemented by a Spill Area Wide Coordinator hired through a contract with the Chugach Regional Resources Commission, and the local facilitators, with the assistance of the Alaska Department of Fish and Game's Division of Subsistence.

The objectives will be achieved using the following methods:

A contract will be let by ADF&G Subsistence Division to CRRC for overall coordination of the facilitators and spill area wide coordinator. The contractor will be expected to arrange for the hiring and coordination of local facilitators in the communities of Chenega Bay, Tatitlek, Port Graham, Nanwalek, and Cordova, Seward, Valdez, and regional coordinators for the Kodiak Island and Alaska Peninsula regions.

Working with the community facilitators, the Spill Area Wide Coordinator will identify those projects funded by the Trustee Council for which a community outreach component would be appropriate, and will work with the principal investigators of those projects to design and implement community outreach components. The goal of community outreach will be to continue the informal partnership, begun under 95052, between the people of the oil spill region and scientific researchers. Outreach will include communication of traditional knowledge and local interests, as well as communication of research proposals and study results. The TEK portion of the project is integral to its success in that the project objectives can only be achieved through a cooperative working relationship between the participating agencies wherein guidelines/protocols are developed, people are trained, and databases shared.

The effectiveness of the project will be evaluated on an annual basis, by the Trustee Council staff working in cooperation with the Spill Area Wide Coordinator, the communities in the oil spill region and the Subsistence Division of ADF&G.

C. Contracts and Other Agency Assistance

A contract will be let to CRRC for overall coordination of a facilitator network through a Spill Area Wide Coordinator. The contractor will be expected to arrange for the hiring and coordination of local

facilitators in the communities of Chenega Bay, Tatitlek, Port Graham, Nanwalek, Seward, Valdez, and Cordova, and regional coordinators for the Kodiak Island and Alaska Peninsula regions.

These tasks are being contracted out for three reasons:

1. The project is expanding in scope and the use of a regional organization as opposed to a state agency would better serve the needs of the local community members.

2. The Trustee Council has encouraged contracting tasks out to the private sector as much as possible, and as appropriate.

3. The state procurement system makes it difficult to contract directly with the communities in the oil spill region. It should prove simpler to contract out the coordination of the facilitator network on a sole source basis with an organization that has an established working relationship with the communities.

D. Location

The project will be undertaken throughout the oil spill region. Local facilitators will be hired in the communities of Chenega Bay, Tatitlek, Port Graham, Nanwalek, Seward, Valdez and Cordova, and regional facilitators will be hired from the Kodiak Island and Alaska Peninsula region. However, all other communities in the oil spill impact area will also be included in outreach efforts, even though a local facilitator will not be hired in each community.

The project's benefits will be realized both in the communities involved and in the restoration of the injured resources. Better communication among the Trustee Council staff, researchers and residents of the communities impacted by the spill, should improve the effectiveness of restoration efforts.

SCHEDULE

A. Measurable Project Tasks for FY 96

October 1, 1995	ADF&G and CRRC enter into contract for coordination of facilitator network
October 1-30, 1995	MOU drafted between ADF&G and CRRC
October 15, 1995	Spill Area Wide Coordinator hired
October - December, 1995	Guidelines/protocols developed for TEK
November, 1995	Identification of injured species for TEK
November, 1995 - January 1996	Preparation for Annual Workshop
January, 1996	Facilitator Network in Place and Operating
January, 1996	Participate in Annual Workshop
January, 1996	Training Workshop for local community facilitators
April, 1996	Training Workshop for local community facilitators
January - September, 1996	Database developed

B. Project Milestones and Endpoints

The project should be continued as long as there are significant restoration efforts underway. The project should be evaluated on a yearly basis to determine the most efficient way to continue to keep the communities involved in the Trustee Council Restoration Program.

C. Project Reports

Annual reports will be compiled in coordination with the Alaska Department of Fish & Game, and provided each year by CRRC on April 15th, describing and summarizing the progress made during the previous federal fiscal year. In addition, bi-monthly reports will be provided to the participating communities by the Spill Area Wide Coordinator.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This community outreach effort is in fact a novel effort to coordinate the Restoration Program with the local residents and builds on the established relationship between CRRC and the communities in Prince William Sound. Under this project CRRC will work to establish new relationships with Kodiak Island and Alaska Peninsula area residents

ENVIRONMENTAL COMPLIANCE

This project is categorically excluded under NEPA guidelines.

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

Project Number:	96064
Restoration Category:	Research
Proposer:	Kathryn J. Frost, ADF&G
Lead Trustee Agency:	ADF&G
Cooperating Agencies:	NOAA
Duration:	3 yrs
Cost FY 96:	$347,300
Cost FY 97:	$347,000
Cost FY 98:	$100,000
Cost FY 99:	$ 25,000
Geographic Area:	Prince William Sound
Injured Resource:	Harbor Seals

ABSTRACT

This project will monitor the status of harbor seals in Prince William Sound and investigate the possible causes for the ongoing decline. Aerial surveys will be conducted to determine whether the population continues to decline, stabilizes, or increases. Seals will be satellite-tagged to describe their movements, use of haulouts, and hauling out and diving behavior. Samples of blood, blubber, whiskers, and skin will be collected to study diet, health and condition, and genetic relationships to other harbor seal populations.

INTRODUCTION

More than 300 harbor seals (36% of the seals in oiled areas) were estimated to have died in Prince William Sound (PWS) because of the *Exxon Valdez* oil spill (EVOS). ADF&G harbor seal studies in PWS began immediately after the EVOS as part of the Damage Assessment program. They included aerial surveys to quantify mortality and necropsies to document levels of hydrocarbons and tissue damage in oiled seals. Beginning in 1991, because harbor seals were damaged by the EVOS, the Trustee Council funded a harbor seal restoration study in which ADF&G continued to monitor the trend of harbor seals in PWS and began to investigate the causes of the ongoing decline.

Annual counts were made of pups and non-pups during June, and all seals during August-September. Surveys showed a normal rate of pupping, but a continued decline in overall numbers. Methodology was developed for catching harbor seals and satellite tags were attached to 26 animals. Results indicated that most tagged seals used only a few haulouts near the tagging site and did not swim far to feed. Three seals traveled to the Gulf of Alaska, then returned to PWS, and a few moved between haulouts in central PWS and glaciers in northern PWS. The deepest dives were over 1,300 ft, but most were 300-450 ft. Blood samples were collected from all seals and tested for disease to see if

seals were healthy. DNA was analyzed to examine whether PWS harbor seals belong to a separate population. Analyses of stable isotopes in whiskers and fatty acids in blubber provided information about seal diets. Results of these initial investigations suggested that disease was not the cause of the decline. Preliminary data indicate differences in the diets of young and adult seals, and seals from different areas.

During 1995, satellite tagging, sampling, and monitoring will be continued. Research will focus on reasons for the decline: 1) Is it disease? 2) Is it low pup production? 3) Is it predation by killer whales? 4) Is it mortality caused by humans (subsistence hunting and/or fishing-related mortality)? 5) Is it food limitation? Aerial surveys will be flown to monitor trends. Satellite tags will be attached to 12 seals. Blood, whiskers, blubber, skin, and measurements will be taken from all seals that are caught during tagging. Similar samples are being collected by ADF&G in southeast Alaska, where harbor seals are not declining. Data will be compared to better understand why seals are doing well in some areas and declining in others.

The research being proposed for 1996-1998 is a continuation and redirection of harbor seal restoration studies that have been funded by the Trustee Council and conducted by ADF&G since 1991. The proposed study will build upon previous research findings and incorporate new components to address high-priority issues regarding harbor seal recovery. Aerial surveys to monitor the trend of harbor seals in PWS will be continued in 1996-1997 and comparisons made to determine whether the decline has stopped. Satellite transmitters will be attached to 12 seals per year in 1996-1997. Fatty acid studies will be expanded to include more prey species, and seals from different seasons/locations. Information on diet will be integrated with data from forage fish studies to understand how harbor seals utilize prey and how they may depend on seasonal or area-specific concentrations of prey.

NEED FOR THE PROJECT

A. Statement of Problem

From 1984-1988, harbor seal counts at 25 trend sites in PWS declined by 43% due to unknown causes. The decline continued in 1989, aggravated in oiled areas by the EVOS. Counts of harbor seals at oiled trend count sites declined by 45%, compared to 11% at unoiled sites. More than 300 harbor seals (36% of the seals in oiled areas) were estimated to have died in PWS because of the spill. Since 1989, harbor seal numbers have continued to decline. There were 28% fewer seals in 1994 than in 1989, and 57% fewer than in 1984. The reasons for this continuing decline are unknown.

B. Rationale

Harbor seals are important to residents of PWS for subsistence. In 1985-1989, harbor seals made up 13%-27% of the subsistence foods harvested in Tatitlek and Chenega Bay. During 1992-1993, these two villages harvested less than half the number harvested annually before the spill. Native residents have noted the scarcity of seals and the impact this has had on subsistence hunting. Harbor seals are

also watched and photographed by tourists and recreational users of PWS and they interact with and are incidentally killed by commercial fisheries.

Like all marine mammals, harbor seals have special federal protection under the Marine Mammal Protection Act (MMPA). Because of the ongoing decline, they are being considered for listing as depleted under the MMPA. It is essential that current population data be available so that inappropriate restrictions on human activities are not implemented. It is also important to understand what factors are limiting the population. We cannot assume, given the ongoing decline, that the number of seals in oiled areas will return naturally to pre-spill levels. It is necessary to continue monitoring trends, to identify and appropriately manage areas of particular biological significance, and to communicate information on population status to subsistence hunters and fishermen in order to minimize mortality and augment recovery in any way possible. Commercial fisheries in PWS may face greater restrictions designed to reduce incidental take of harbor seals unless something can be done to understand and reverse the population decline.

The ongoing declines of harbor seals began over two decades ago in the Kodiak area, and were detected at least a decade ago in PWS. Although periodic surveys have documented these downward trends and are useful for determining whether the recovery objective of "stable or increasing population trends" has been met, they are not adequate for determining what is causing the seal population to decline, or for designing conservation and management measures to facilitate recovery and ensure the future health of the population. 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 and mitigating the decline. Similar declines have occurred in Steller sea lions, also for unknown reasons. For both of these species, it has been suggested that changing prey availability may be an important factor. 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. Information is also needed about health and disease, stock identity, and sources of mortality.

C. Summary of Major Hypotheses and Objectives

The objectives of this study are to monitor the abundance and trends of harbor seals at trend count sites in oiled and unoiled areas of PWS; to gather data on the behavior and habitat use of harbor seals in PWS that can be used to design effective conservation measures; to investigate trophic interactions in order to better understand whether food is limiting the harbor seal population; to model the effects of different sources of mortality on harbor seals; to determine whether disease is contributing to the decline; to determine whether poor pup production is contributing to the decline; to determine the genetic relationships among harbor seals in PWS, and other parts of Alaska; and to provide information to subsistence hunters so they can make informed decisions about the level of harvest for harbor seals.

The hypotheses that will be tested include: 1) harbor seals in PWS have stabilized or increased since the EVOS; 2) a disease agent is causing harbor seals to decline ; 3) harbor seals in PWS belong to a

separate management stock; 4) low pup production is causing harbor seals to decline; 5) killer whale predation is causing the decline or preventing recovery; 6) mortality caused by subsistence hunting and/or fisheries-related take is preventing harbor seals from recovering; and 7) a change in food availability has caused harbor seals to decline.

D. Completion Date

This project will take place in three fiscal years. Field work and laboratory analyses will be conducted during FY 96 and FY 97. Final data analyses will be conducted and a final report prepared in FY 98.

COMMUNITY INVOLVEMENT

Information from this study will be presented at oil spill symposia, planning workshops, conferences, and in the published literature. Information will be provided to Sea Grant and ADF&G Division of Subsistence for use in meetings and discussions with PWS subsistence hunters. ADF&G marine mammals staff regularly attend meetings with various public groups (tourism industry, fisheries, conservation groups, subsistence communities) to inform them about status, important conservation issues, and key research needs for harbor seals.

Project investigators will cooperate with personnel from the ADF&G Division of Subsistence (Project 244) in their efforts to inform residents of Chenega Bay, Tatitlek, Valdez, and Cordova about the findings of this study and to incorporate the suggestions of PWS residents in study design. Such an exchange of information will allow biologists to benefit from residents' observations about abundance and behavior of harbor seals in PWS, and will help residents to make informed decisions about their annual harvest of harbor seals.

Investigators are working with the Alaska Native community towards the creation of an Alaska Harbor Seal Commission. Investigators will assist in any way possible in developing community-based harvest monitoring and sampling programs. Project personnel will facilitate sample analysis and communication of results to community residents. A short annual report that summarizes the results of harbor seal investigations will be prepared for distribution to PWS community residents.

PROJECT DESIGN

A. Hypotheses and Objectives

Hypothesis 1: The PWS harbor seal population has stabilized and/or increased since the EVOS.

1. Conduct aerial surveys at PWS trend sites during pupping and molting in 1996 and 1997;
2. Correct counts for effects of date, weather, time of day, and tide using historical PWS survey data base and information from satellite-tagged seals;

3. Compare counts to data from 1989-1994 to determine trend;
4. Model the effects of mortality caused by the EVOS on harbor seal population dynamics.
5. In 1998, reevaluate all survey data collected since 1989 to evaluate whether seal numbers are continuing to decline, have stabilized, or are recovering to pre-spill levels.
6. Based on observed trend and statistical characteristics of survey data, recommend a monitoring schedule for 1998 and beyond.

Hypothesis 2: A disease agent is causing harbor seals to decline.

1. Collect blood samples and analyze them to determine whether harbor seals in PWS are infected by a viral disease that may be causing or aggravating the harbor seal decline;
2. Examine all seals that are handled during tagging for external signs of disease; and
3. Archive serum samples for future testing of currently unidentified disease agents.

Hypothesis 3: Harbor seals in PWS belong to a separate management stock.

1. Collect and analyze genetics samples from PWS seals and compare to seals from other regions to evaluate whether PWS seals constitute a genetically distinct management stock;
2. Examine regional genetic variation within PWS; and
3. Tag subadult and adult harbor seals in PWS to study their movements and site fidelity.

Hypothesis 4: Low pup production may be causing harbor seals to decline.

1. Conduct surveys during pupping in June to determine the number and proportion of pups;
2. Compare pup production in PWS with production in areas where harbor seal populations are stable or increasing; and
3. Incorporate pupping data into a population model to evaluate whether pup production is limiting population growth in PWS.

Hypothesis 5. Predation by killer whales is causing the decline or preventing recovery.

1. Estimate the number of harbor seals eaten by killer whales in PWS (in cooperation with and using data from project 012 -Comprehensive Killer Whale Investigation); and
2. Model the impact of killer whale predation on PWS harbor seals.

Hypothesis 6: Mortality caused by subsistence hunting and/or fisheries-related take is preventing harbor seals from recovering.

1. Obtain harvest data for harbor seals in PWS from community-based harvest monitoring program;
2. Obtain information on incidental take of harbor seals from NMFS observer data;
3. Model the impact of human-caused mortality on PWS harbor seals; and
4. Meet with hunter representatives and discuss the implications of population modeling.

Hypothesis 7: A change in food availability (quantity and/or quality) has caused harbor seals to decline.

1. Measure seals in PWS and develop condition indices for interannual comparisons and comparison to historical data base from the late 1970s (with project 001);

2. Provide historical and recent blubber samples to project 117 for analysis of energy content and whiskers to project 320-I for analysis of stable isotopes;
3. Compare dietary information from harbor seals in 1970s with recent data;
4. Determine individual, age-related, seasonal, and interannual differences in diets of seals as measured by fatty acid composition of lipid stores, stable isotopes of whiskers (stable isotope analyses by project 320-I), and stomach contents as available from hunters;
5. Evaluate the relative contribution of each prey type to the overall diet using measured fat content of the prey, and compare energy value of prey eaten by adults and subadults (with APEX);
6. Assess variation in the fatty acid composition of prey species (with APEX and project 012);
7. Determine feeding areas (location/depth) of seals based on satellite-tagging data and describe the use of and movements between haulouts and feeding areas;
8. Describe hauling out and diving behavior, and by inference, feeding behavior of satellite-tagged seals in PWS; and
9. Compare information about diet and feeding areas with information about forage fish distribution and abundance (incorporating data from SEA, APEX, and herring studies).

B. Methods

We are proposing two additional years of field study (1996, 1997) with final data analysis and reporting to take place in 1998. 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 studies. In addition to the seven components outlined in this project description, questions about harbor seal health and condition, stable isotope analyses, predation by killer whales, and prey availability will also be addressed by other Restoration studies.

Aerial Surveys and Analysis (Objectives 1.1, 1.2, 1.3, 1.5, 1.6., 4.1, 4.2)

Harbor seal abundance will be monitored by flying aerial surveys during pupping (June) and molting (late August-early September). A fixed-wing aircraft will be used to survey 25 trend count sites at an altitude of 700-1000 ft. These haulout sites have been used by ADF&G for PWS harbor seal trend counts since 1983, including NRDA and Restoration studies in 1989-1994 (Calkins and Pitcher 1984; Pitcher 1986, 1989; Frost and Lowry 1994a; Frost et al. 1994a). The trend count route includes 7 sites that were impacted by the EVOS (Agnes, Storey, Little Smith, Big Smith, Seal, and Green islands, and Applegate Rocks) and 18 unoiled sites (Table 1, Figure 1). The survey methodology and observers will be the same as those used in PWS harbor seal studies conducted in 1989-1994 (see Frost and Lowry 1994a; Frost et al. 1994a), and as summarized below.

Maximum numbers of harbor seals are known to haul out during pupping and molting (Pitcher and Calkins 1979; Calambokidis et al. 1987). Within these periods, more animals are usually hauled out at lower stages of the tide, since availability of many haulout sites is limited by tidal stage. Consequently, our surveys will be conducted during June (pupping) and late August/September

(molting), and will begin within two hours before daylight low tides and finish within two hours after low tide. Replicate counts will be made at each site to allow statistical analysis of trend.

Power analysis of data from 1989-1994 indicates that in order to detect a 5% change per year over a five year period ($p=0.05$) with a greater than 50% probability of being right (using initial population = 1050, the number of seals at trend count sites in 1988), it is necessary to fly annual surveys with 7-10 replicates per year (Figure 2). This analysis was based on data collected by ADF&G since 1984, and takes advantage of one of the most extensive data sets of its kind. The recommendation of 7-10 replicates is similar to the number of replicates recommended by Pitcher based on analysis of other harbor seal surveys in Alaska (Pitcher 1986, 1989). The number of replicates also may be influenced by weather, which can limit the number of days suitable for flying within a survey period.

Visual counts will be made of seals at each site, usually with the aid of 7 power binoculars. Pups will be counted separately during June. Photographs will be taken of large groups for later verification using a hand held 35-mm camera with 70-210 mm zoom lens and high speed film (ASA 400). Color slides will be commercially developed and the seals will be counted from images projected onto a white surface.

Aerial surveys do not estimate the total number of seals present since they do not account for seals that are in the water or seals hauled out at locations not on the trend count route. Surveys provide indices of abundance based on the number of hauled out seals. Interpretation of trend count surveys relies on the assumption that counts of harbor seals on select haulout sites are valid linear indices of local abundance. We assume that within a given biological window, such as the molting period, hauling out behavior remains the same from one year to the next, and counts can thus be compared (e.g., Harvey 1987, Pitcher 1989). Standardization of procedures minimizes the affects of variables such as tide and weather that could influence the number of seals hauled out on a given day. In addition, for all future PWS surveys the results of a multivariate analysis conducted based on survey data from 1989-1994 will be used to correct counts for weather, tide, and date. These corrections were developed in 1995 and will be presented in the 1995 Annual Report (see Figure 3). During 1995 and beyond, additional multivariate analyses will be conducted on a site-by-site basis to examine the effects of tide, date, and weather parameters on individual sites and to learn which areas produce the most stable counts and which are the most variable. Behavioral data obtained from satellite transmitters attached to seals as part of this study will help to verify these assumptions. Satellite tags will also help to provide estimates of the proportion of seals hauled out at low tide which can be used to develop correction factors for estimating the total number of seals present, not just those that are hauled out and available to be counted.

Reliable surveys of the trend count route were conducted during the molt in 1984 and 1988-1994. These data will be used for comparisons with data collected in 1995 and later. Analyses of trend count data and comparisons with other years will be conducted following statistical methodology used for previous surveys (Frost and Lowry 1994a, b; Frost et al. 1994a). For each year, daily surveys will be averaged for each site and then sites will be summed to produce yearly estimates for the oiled, unoiled, and total trend count areas. The 95% confidence interval will be estimated by bootstrapping

(Efron and Tibshirani 1993). The bootstrap method resamples with replacement from the actual daily counts at each haul-out site to produce a new data set with the same sample size (number of counts) for each site in each year. This resampling will be done 2000 times for each year's data, and then the 2000 bootstrap estimates will be ordered. Ordinarily, the 50th and 1950th ordered bootstrap estimates provide a 95% confidence interval, but as recommended by Efron and Tibshirani (1993), we will use a bias-corrected version that slightly adjusts the choice of the ordered bootstrap estimates for the confidence interval endpoints.

A linear regression model will be fitted to yearly estimates at oiled sites, unoiled sites, and for the trend count area as a whole for uncorrected data and for data corrected for the effects of date, time, tide, and weather. This will be done for both pupping and molting counts. During the pupping period, only the counts of non-pups will be used in the analysis. The regression line for each group will take the form,

$$Y = b_0 + b_1(X)$$

where Y is the mean count/site summed for all sites, b_0 is the y intercept of the line, b_1 is the slope, and X is the year. The significance of regression coefficients will be tested using analysis of variance (Snedecor and Cochran 1969).

Catching and Sampling Seals (Objectives 2.1, 2.2, 3.1, 7.1, 7.2, 7.4)

Seals will be caught by entanglement in nets placed near the haulouts. Nets will be approximately 100 m long and either 3.7 or 7.4 m deep with standard floats or float line and light lead lines. Mesh openings will be about 30 cm stretched measure. Nets will be deployed from a 6 m boat assisted by one or two other small boats to assist in maneuvering the net and tending it to ensure that all captured seals are quickly detected and removed (see Frost and Lowry 1994b).

When seals become entangled, they will be brought into the boats or to shore, cut free from the tangle net, and placed into hoop nets (large stockings made of 1 cm mesh soft nylon webbing). Smaller seals will be physically restrained during handling and tagging. Larger animals will be sedated with a mixture of ketamine and diazepam administered intramuscularly at standard doses (Geraci et al. 1981). Each seal will be weighed, measured, and tagged in both hindflippers with individually numbered plastic tags. Field personnel will collect approximately 50 cc of blood from the extradural intervertebral vein. Ultrasound measurements of blubber thickness will be made whenever possible. Standard blood chemistry panels and virology screens (phocine distemper virus, herpes, and others as indicated) will be run on these samples. The following samples will also be taken: whisker(s) for stable isotope analysis (project 320-I), a small piece of skin for genetics studies, and a 0.5 cm x 2.5 cm blubber biopsy for fatty acid analysis and analysis of energy content (project 117). Seals will be selected by age and sex for instrumentation with satellite tags, as described below.

Seals will be caught in three regions of PWS to coincide with sampling areas being used by other studies (APEX, SEA, and herring studies). These will be Port Gravina; southern PWS near

Montague, Green, and Little Green islands; and central PWS near Agnes, Smith, and Seal islands. This will facilitate comparison of data obtained by fish, seabird, and harbor seal researchers about important prey species and responses to changing availability of prey. Hydroacoustic and trawl data will be available from these areas. If a suitable technique can be developed for catching seals near glacial ice, we will sample seals from a glacial fiord (probably Icy Bay where APEX bird studies will be occurring) where prey base and feeding behavior may be very different from that in other habitats. We will try to catch and sample approximately 50 seals total per year, during April-May and September. If sample analyses indicate that other areas or seasons should be sampled, we will extend or modify our sampling schedule.

Disease (Objectives 2.1, 2.2, 2.3)

Recent epidemics and mass mortality caused by phocine distemper virus in the eastern North Atlantic have highlighted the possible role of disease in marine mammal population declines (Heide-Jorgensen et al. 1992, Thompson and Hall 1993). Since 1989, as part of this and other harbor seal studies, we have been collecting samples for disease investigations. To date, 84 seals from the study area have been screened for phocine distemper virus (72 negative, 12 positive) and 97 for herpes virus (30 negative, 67 positive) (R. Zarnke, pers. commun.). Serum from 98 other seals sampled since 1991 has been sent in for analysis. Seventeen seals sampled in the Kodiak area during 1993 were tested for caliciviruses (including San Miguel sea lion virus), and all were negative (J. Lewis, pers. commun.). Swabs and/or serum from 5 Kodiak-area seals and 13 PWS seals have been screened for Chlamydia; most samples were negative (J. Lewis, pers. commun.). The only potentially pathogenic bacteria found in bacterial swabs from 27 PWS seals and 5 Kodiak seals sampled in 1993 were *Moraxella* sp., *Paturella* sp., and *Bordatella bronchiseptica*. These organisms can occasionally cause disease in domestic animals. All can occasionally cause pneumonia, and *Moraxella* sp. can cause conjunctivitis. However, in otherwise healthy seals it is unlikely that they would cause a problem (T. Spraker, pers. commun.).

Although at this time it appears unlikely that disease is responsible for the ongoing decline of seals in PWS and the Gulf of Alaska, we will continue to collect samples, conduct some analyses, and archive serum for disease screening. The cost of this component is minimal and it allows us to track the health of seals in the study area. During 1995 and beyond, blood will be collected from all seals that are handled during tagging. Serum will be obtained for viral screening, and assays will be conducted for phocine distemper virus, seal herpes virus, and any other viral agents that might be of concern. Additional serum will be archived at ADF&G Fairbanks for future use.

Genetics (Objectives 3.1, 3.2)

Measures of genetic diversity are useful for evaluating gene flow among seals in different geographic locations, and in assessing whether particular groups of seals constitute separate biological stocks. This information is important for several reasons. First, it is not possible to put mortality caused by an event such as the EVOS into perspective without some understanding of population structure. In other words, did the 300 seals that died following the EVOS represent 30% of a central PWS stock, 5-

10% of a stock that includes all of PWS, or a much smaller percent of either a Gulf of Alaska stock or an Alaska-wide stock? Information about stock identity and stock size is also necessary for evaluating the impact of mortality caused by subsistence hunting, incidental take by fisheries, or predation. It is not possible to recommend a safe harvest level for harbor seals in PWS without knowing the size of the stock from which the harvest is taken.

Use of molecular genetic techniques can help clarify whether seals in adjacent areas are genetically discrete from one another, and provide managers with a better concept of the overall harbor seal population structure, including estimates of gene flow between colonies and site fidelity. Lehman et al. (1993) detected geographic partitioning in harbor seals from PWS, Washington, and California based on genetic variation in minisatellite loci. However, only three seals from a single location in Alaska were included in that study. Lamont and Thomas (1994) found considerable diversity in harbor seal mitochondrial DNA sequences from Washington, Oregon, and California. Although in that study many haplotypes were unique to certain localities, small sample sizes precluded conclusions regarding the amount of gene flow.

Mitochondrial sequence diversity will be used to investigate genetic structure among groups of harbor seals in Alaska and within PWS. Small skin samples for genetics analysis will be taken from all seals that are captured during tagging operations in 1995 and beyond. Similar samples were also obtained from seals captured in PWS during 1993-1994, and from seals collected for food safety testing in 1994 (Project 95279). Comparative samples are available from the NOAA-funded ADF&G harbor seal study in Kodiak and southeast Alaska.

Pieces of skin will be taken from the hind flipper of each seal using a 0.5 cm diameter skin punch, and preserved in DMSO-salt solution until they are analyzed. Analyses will be conducted by the genetics laboratory at the NMFS Southwest Fisheries Science Center in La Jolla, CA. DNA will be amplified using polymerase chain reaction procedures, and fragment and sequence analyses will be conducted. Polymorphic mitochondrial DNA sequences and polymorphic nuclear DNA alleles will be sought as markers for morphological, geographic, and management stocks. Preliminary analyses of samples from harbor seals and spotted seals in Alaska have demonstrated that this technique produces useful results (O'Corry-Crowe and Westlake 1994).

Modeling (Objectives 1.4, 4.3, 5.3, 6.3)

A demographic model will be developed and refined in cooperation with biometricians from the NMFS National Marine Mammal Laboratory, to examine the effects of predation, harvest, and incidental take on the harbor seal population in PWS. An age-specific mortality curve will be generated using life tables from PWS harbor seals developed by ADF&G in the 1970s (Pitcher 1977; Pitcher and Calkins 1979). Age-specific fecundity rates will be estimated from pregnancy rates derived from this same data set. Data on the subsistence harvest will come from ADF&G's Division of Subsistence (Project 244 and others), obtained in cooperation with subsistence hunters from Chenega Bay, Tatitlek, Cordova, and Valdez (see Wolfe and Mishler 1993), and from a community-based monitoring program to be developed in 1995-1996. Information on killer whale predation will

be obtained from the Comprehensive Killer Whale Investigation (Project 012), as well as from other pertinent studies (e.g., Saulitis 1993). Data on incidental take in fisheries will be obtained from NMFS, and other sources such as Wynne (1990).

Estimates of mortality and reproduction will be combined to produce a population model following that proposed by Eberhardt (1985). It is unknown what specific change in mortality or fecundity has occurred since the samples were collected in the mid-1970s; all that is known is that the population has been declining. Neither is there a known change in a specific demographic parameter (for example increased mortality of pups or subadults) which should obviously be used to modify the base-line model. Thus, the demographic parameters will be adjusted by various amounts, first individually and then together, to determine what changes would result in the observed rate of change. The amount of time for which the model will be "allowed" to produce the observed rate of change will not be greater than 10 years, approximately the amount of time between when the samples were collected in the 1970s and the start of the decline.

To address the question of how various mortality factors (subsistence harvest, killer whale predation, commercial fishery kill) may affect the population, we will first determine the estimated annual mortality at the current and 1984 levels. This estimate will be compared with estimates from various mortality factors. The mortality schedule within the model will be adjusted following the estimates, and the resulting population status explored. This modeling outline is based on the assumption of a closed population, or similarly that emigration equals immigration. Information from genetics studies and data from satellite-tagged seals will be used to evaluate this assumption.

Satellite-tagging (Objectives 1.2, 3.3, 7.7, 7.8, 7.9)

Satellite-linked telemetry can be used to gather information about habitat use, including site fidelity, movements between haulout sites and in and out of PWS, seasonal changes in hauling out patterns, habitats used for feeding, and feeding and diving behavior. Satellite-linked time-depth recorders (SLTDRs) have provided researchers with the ability to monitor location and diving behavior of marine mammals (Mate 1986, 1989, Hill et al. 1987, Stewart et al. 1989, Lowry et al. 1994, Frost and Lowry 1994b). The SLTDRs transmit to a satellite-based Doppler positioning system that calculates locations and tracks movements of animals with considerable accuracy. When combined with appropriate environmental sensors and microprocessor hardware and software, other information about an animal's environment and behavior can be transmitted to the satellite.

This study has demonstrated that SLTDRs are an effective means of monitoring the movements and haulout locations of harbor seals in PWS. During 1991-1994, significant data were received from SLTDRs attached to 26 harbor seals in PWS, including 17 males and 9 females (Table 2). Nineteen were adults and 7 were subadults. SLTDRs were attached to 17 seals from areas in central PWS that were oiled by the EVOS (Seal Island, Herring Bay, Bay of Isles, Applegate Rocks); one from eastern PWS (Gravina Island); and eight from unoiled sites in southcentral PWS (Port Chalmers and Channel Island). SLTDRs were operational for up to 10 months, and provided locations for more than 75% of those days.

SLTDRs deployed during 1991-1994 indicated that the movements of harbor seals were mostly confined to within PWS. Many seals hauled out only at the tagging location, although some also used one or two nearby locations (Frost and Lowry 1994b). Movements between terrestrial haulouts in central PWS and glaciers in northern PWS were not uncommon. Three seals made substantial movements to the Gulf of Alaska or the Copper River delta, but later returned to PWS. These movements were mostly made by subadult seals.

Most areas where seals were diving and probably feeding were within a few kilometers of haulouts. However, one seal spent several days 30 km from the nearest land in the Gulf of Alaska. The deepest dive by a tagged seal was 404 m, but most dives were to less than 200 m. SLTDR sensors indicated that 58% of 64,000 dives monitored during 1992-1993 were less than 50 m, 39% were 50-150 m, and only 3% were deeper than 150 m. The usual maximum depth for seals smaller than 50 kg was 100-130 m, compared to 130-150 m for seals larger than 50 km (Frost and Lowry 1994b). In combination with data being collected on abundance and distribution of forage fishes and about the prey being utilized by harbor seals in PWS, these SLTDR data will help us to better understand feeding behavior of adult and subadult seals. In addition, they should help us to develop correction factors to be used in interpreting aerial survey data (e.g., Harvey 1987).

During 1996 and 1997, SLTDRs will be attached to 12 seals per year at locations chosen because they appear to represent different habitat types, because of their apparent importance to seals, and/or for their proximity to forage fish and oceanographic stations sampled as part of other PWS ecosystem studies. This will include Gravina Bay (important herring area), southern PWS near Montague, Green, and Little Green islands (herring and fish data from here, and a large number of seals); and central PWS near Agnes, Smith, and Seal islands (APEX fish data available, and significant seal haulouts). Actual tagging locations will depend on where seals are present and can be caught. At present we have no method that is suitable for catching seals in areas with drifting glacial ice. If we can develop such a method, we will instrument some seals from glacial fiord areas (Icy Bay, Columbia Bay, etc.).

Emphasis will be placed on instrumenting subadult seals and adult females. Approximately four of the SLTDRs will be put on adult females and the remaining eight units on small subadults of either sex. This sex/age distribution of tags may be modified somewhat based on results of ongoing data analyses and/or conditions experienced in the field. Depending on the performance of tags in 1995 and whether it is considered desirable to tag additional pregnant females, it is likely that in 1996 and 1997 seals will be instrumented only in September.

Transmitters (14 cm x 10 cm x 4 cm for adults; 14 cm x 5 cm x 4.5 cm for subadults) will be attached to the mid-dorsal surface of the seal by gluing with epoxy resin (Fedak et al. 1984; Stewart et al. 1989). SLTDRs attached in autumn following the molt should remain attached until the next molt, but may not operate that long. Mean duration of operation of SLTDRs attached in fall 1993 was 182 days, with a range of 102-311 days (Frost and Lowry, unpublished). Small units suitable for subadults that were deployed in 1994 lasted up to 150 days. Tagging during the winter months is not considered cost-effective or practical. The weather is often severe, the water extremely cold making it

difficult to work, and few seals are hauled out. Some SLTDRs were duty cycled in September 1994. Others will be duty-cycled in September 1995. Based on results from these tags, and if this effectively extends the data acquisition period through the pupping period, we may duty cycle all SLTDRs in 1996 and 1997.

Data will be acquired from the ARGOS satellite receiving system and initially analyzed using software provided by the manufacturer of the transmitters. Each SLTDR will transmit signals to polar-orbiting satellites whenever the seal is hauled out or when it surfaces sufficiently long for a transmission to occur. An uplink occurs when a satellite is positioned to receive the signal. Information transmitted by the SLTDR is used by Service ARGOS to calculate the geographic location of the seal. Units will be equipped with built-in programmable microprocessors to collect and summarize data for periods when animals are diving and store it for later transmission, as has been done for crabeater seals, Steller sea lions, and spotted seals (Hill et al. 1987; R. Merrick, personal communication; Lowry et al. 1994a). These data will be stored in six hour blocks and transmitted to the satellite once the six hour data collection period is complete. Sensor information from a pressure transducer and a conductivity switch will be used to indicate when the animal is hauled out. Data from four periods will be stored in memory, providing at least a 24 hour window for transmission before the data are lost. Dive data will be summarized as histograms in depth bins of 4-20 m, 21-50 m, 51-100 m, 101-150 m, 151-200 m, 201-250 m, 251-300 m, 301-350 m, and over 350 m, and duration bins of 0-120 seconds, 121-240 seconds, 241-360 seconds, 361-480 seconds, 481-600 seconds, 601-720 seconds, 721-840 seconds, 841-960 seconds, 961-1080 seconds, and over 1080 seconds. In addition, SLTDRs will store and transmit the amount of time spent in each depth bin and the total time spent at the surface.

Each SLTDR broadcasts a unique identification code so that data can be assigned to a particular seal. Position accuracy for all geographical locational information is rated by Service ARGOS to reflect the predicted accuracy of the calculated locations (Fancy et al. 1988, Stewart et al. 1989). Locations calculated by Service ARGOS will be screened for accuracy and plotted on charts of PWS. Locational data will be compared with sensor data, when possible, to verify that information regarding whether the seal is on land or at sea is correct, since errors in calculated locations may falsely indicate that a seal is on land or at sea (see Stewart et al. 1989).

Data on the haulout patterns of tagged seals will be examined for indications of daily or seasonal variations, for example to determine whether there is a change in the frequency of haulout by season, or whether the amount of time spent hauled out changes. Plots of locations where continuous signals are received will be used to determine the degree and regularity of use of particular haulout sites. We expect to receive fewer locations of seals while at sea, because the transmitter antenna will frequently be submerged. At-sea locations will be plotted as an indication of areas used for feeding. Information on depth and pattern of diving will be compiled, and will provide additional information on the general areas used for feeding.

Dive data will be presented as graphs and histograms which indicate the range in individual behavior as well as summary data for all seals combined. Dive data histograms will present the number of

dives at different depth increments and by duration of dive. Means and standard deviations for dive depth and duration will be calculated and compared for seals in different locations or habitats and at different times of day and year. Compilation of data on time and location of feeding dives will be used to identify feeding areas near different haulouts, if possible. If sensors indicating whether the seal is on land or at sea become more reliable and the necessary SLTDR software is developed to provide a continuous record of this information, then diving and hauling out cycles will be examined relative to time of day, tide, and season. Summaries of the number and quality of uplink data and at-sea position data will be presented in tabular form. Tabular summaries will also be prepared for use of different haulouts by individual seals; the number of haulout bouts relative to tidal state and time of day; and frequency of haulout and amount of time spent feeding by season.

These data will be used to develop correction factors for surveys, to evaluate site fidelity of seals, to quantify the amount of interchange among haulouts within and outside of the area impacted by the EVOS and within and outside of PWS, to determine seasonal importance of particular haulouts, to identify areas used for feeding, and to reveal differences in movements and feeding behavior of subadult and adult seals.

An alternate methodology to satellite-tagging is the use of VHF telemetry. VHF transmitters are inexpensive to purchase. They are quite reliable for short distances when signals are not obstructed by geographic barriers, and are useful for monitoring attendance at particular haulouts (e.g., Harvey 1987). However, monitoring of VHF transmitters can be expensive and labor intensive; they must be tracked either from aircraft or by field personnel stationed near the tagging location. During much of the year, weather in PWS is foggy and stormy, and flying is either precluded or dangerous. Remote monitoring stations are of limited utility because of the topography in PWS. If the seals swim more than a few miles from the monitoring station, or around an island with significant geographic relief, the signals can no longer be acquired. It would be difficult to relocate seals if they swim long distances in unpredictable directions as some of the SLTDR- tagged seals have done. In PWS, VHF technology could only give an indication of some of the haulouts that are used by a tagged seal, and of its activity patterns while it is on that particular haulout.

Satellite telemetry is a preferable alternative to VHF telemetry in PWS. SLTDRs transmit data regardless of whether investigators are in the field to monitor them. They do not require the use of aircraft or field stations. Data transmission is not limited by weather or time of day. Micro-processors allow data to be stored for a 24-hr period, greatly increasing the probability that a transmission will be sent when a satellite is overhead. Every time that a seal surfaces for a sufficiently long period of time, data are transmitted. Such data give a much more complete picture of movements and hauling out behavior than do intermittent VHF data. The SLTDRs provide data on duration and depth of dives, and the time spent in particular depth increments, that are not available from conventional VHF transmitters.

Fatty Acids (Objectives 7.3, 7.4, 7.5, 7.6, 7.9)

Recently, a method has been developed for understanding marine food webs through the use of fatty acid signatures (Iverson 1993). Fatty acids are essentially the building blocks of lipid. Organisms are able to biosynthesize and modify fatty acids, but there are biochemical limitations and differences in these processes depending on the organism. Specific fatty acids cannot be synthesized by animals and therefore can only originate from diet. Because of this, some fatty acids in the food chain can be attributed to specific origins (Cook 1985). Lipids from marine organisms are characterized by a very complex array of fatty acids. There are substantial differences in fatty acid composition among species and prey types, as well as within species by geographic region (e.g. Ackman et al. 1975, Iverson 1993). In marine mammals, dietary fatty acids are often deposited in body tissue without modification (Iverson and Oftedal 1992, Iverson et al. submitted). Consequently, 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.

This concept of fatty acids as trophodynamic tracers can be applied to harbor seals. In general, lipid transfer from prey to deposition in tissue is extremely efficient (Iverson 1988, Iverson et al. submitted). Because certain fatty acids cannot be biosynthesized by seals, they are known to be of dietary origin. For example, a pair of monosaturates that occur in one species of copepod act as a tracer in Atlantic cod and herring (Ackman 1980). Since most seals undergo seasonal periods of fasting and depletion of fat stores (e.g., during the breeding season or the molt) followed by intensive blubber deposition (prior to the subsequent breeding season), blubber fatty acids usually reflect the integration of diet over a period of several months. In contrast, circulating chylomicrons in blood carry the lipid specifically from the last meal. Thus, fatty acids in blubber and blood provide information on both immediate diet as well as dietary history of the animal. Since many seals tend to feed on only a single or few selected prey species at a given time or season (e.g., Bowen 1990), this facilitates the use of fatty acid signatures.

During a pilot study in 1994, 41 blubber samples were obtained. Preliminary analysis of these samples indicated substantial individual and geographic variation, suggesting differences in feeding modes. Two adult, pregnant females from Stockdale Harbor and Port Chalmers had different fatty acid signatures than did two subadult males from the same general area (Iverson, unpubl. data). Seals from Port Chalmers had eaten very different prey than seals at Channel Island only a few kilometers away. This is unlike harbor seals from Sable Island, Nova Scotia, which show little individual variation (Iverson, pers. commun.). Ratios of particular fatty acids in PWS seals were quite different than ratios found in seals in the Atlantic or sea lions in California. It is likely, once prey species have been analyzed, that these unusual isomers can be attributed to particular prey. The stable isotope composition of the whiskers of these same seals was also quite different, both at the time of sampling and along the length of the whisker (A. Hirons, pers. commun.). Whiskers of two adult females showed large changes in del 13C (-12.5 to -17.5) and del 15N (18 to 13), suggesting changes in diet along the length of the whisker. In contrast, two young males appeared to have been eating prey at the same trophic level throughout the period represented by the whisker. Their isotope ratios showed little change: del 13C ranged from -15.5 to -16.5 and del 15N from about 17 to 16 (Hirons, unpubl.

data). If whiskers are replaced annually, these stable isotope data may suggest that adult females utilize very different prey in winter than at other times of year, or that they feed in different areas.

Blubber samples will be taken from seals using routine biopsies (sterile 6 mm biopsy punches). Samples will initially be collected in spring and fall to coincide with possible seasonal changes in feeding behavior and blubber depletion/deposition. Samples will be placed in chloroform/methanol with BHT as an antioxidant, and kept frozen until analyzed. Samples will be collected from all seals that are caught during tagging operations. Blood will be collected from the same animals and centrifuged in the field. If chylomicrons are evident (milky white or cloudy serum, indicating recent feeding) the serum will be separated, preserved, and stored frozen for later fatty acid analysis. Prey species will also be analyzed by the APEX study and/or this study.

During 1996-1997, fatty acid analyses of seal blubber and serum and prey samples collected in previous years will be completed. In addition, approximately 50 additional harbor seals per year will be biopsied and analyzed for fatty acids (from both spring and fall, and representing different parts of PWS). Approximately 10 species of prey that are potentially important dietary items will be sampled during spring and fall. For each species and season, 8 individuals of the size range likely to be consumed by seals will be collected and will be analyzed separately for total fat and protein content and fatty acid composition. Prey species determined to be most important in the diet will be examined in more detail. Seals will continue to be sampled from different parts of the study area. A broader range of prey species will be selected only if the initial ones chosen were not appropriate. Samples will be obtained from herring and APEX forage fish projects. They will be frozen whole in plastic bags and stored frozen until extraction and lipid analysis.

Laboratory analysis and evaluation of data will be conducted by Dr. Sara Iverson at Dalhousie University, Nova Scotia. Fatty acids will be extracted from seal blubber and prey according to methods described in Iverson (1988). Blood samples containing chylomicrons will be processed by ultra-centrifugation after adjusting serum density with sodium bromide and layering with various density salt solutions. Chylomicrons will be decanted from other blood lipoproteins and extracted. Fatty acid methyl esters will be prepared directly from aliquots of the chloroform extract, then extracted and purified in hexane. Analysis of fatty acid methyl esters will be performed according to Iverson et al. (1992) using temperature programmed capillary gas liquid chromatography and linked to a computerized integration system. Identifications of rare isomers will be performed using techniques such as hydrogenation and silver nitrate chromatography (Iverson et al. 1992). Approximately 70 fatty acids and isomers can be separated and quantified in most marine lipids. The proper isolation of all components in any sample is critical in assessing diets and prey items; these methods are currently set up and routinely used in the Dalhousie University laboratory of Dr. Iverson.

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. In the analysis and interpretation of data, fatty acids will be grouped as: 1) components which could readily be biosynthesized by the seal; 2) components that

could be biosynthesized but at the measured levels are likely mostly of dietary origin; and 3) components that could only come from the diet. Categories 2 and 3 represent the "indicator" fatty acids (Iverson 1993).

Data will be analyzed using a multivariate model called a tree regression analysis (Clark and Pregibon 1992). This model has recently been applied and modified for fatty acid signature analysis (Iverson pers. commun.). The model considers all 70 component fatty acids in each sample and uses the fatty acid arrays of species to determine classification rules for types of signatures. The model builds complex trees through which predator (seal) samples are run for appropriate classification (i.e., diet). Through this method we will attempt to differentiate prey species being consumed, as well as geographical, seasonal, or interannual differences in diet. The quantitative contribution of each prey species to a given seal's diet can be estimated from its total fat content based on proximate analysis and its fatty acid signature.

The use of fatty acids to elucidate diet and trophic relationships is in the developmental stages. It is not a stand-alone method, but neither is any other currently available method for examining marine mammal diets. Stomach contents analysis is limited by our ability to obtain large enough samples, the digestive state of contents, and by the fact that food in a stomach represents a single meal. In PWS, large tidal fluctuations every 6 hours make it virtually impossible to collect scats from areas where seals haul out. Stable isotopes indicate the trophic level at which seals feed and temporal variations in prey type, but provide little information on specific prey. Studies of prey availability are necessary to establish the "menu" from which seals may choose, but they do not reflect the availability of prey to seals or the energetic costs of capturing different prey. Progress towards answering the question of "Is food limiting harbor seals?" will most likely come through the combination and integration of a variety of approaches, including analyses of fatty acids, stable isotopes, and stomach contents; investigations of the distribution and abundance of potential prey; evaluation of body condition and changes in condition through time; blood chemistry; and analyses of blubber as an energy source. Each of these approaches will provide pieces to a very intricate puzzle, and together they will give us a better understanding of the trophic dynamics of seals in PWS. In aggregate, the studies funded by the Trustee Council for 1995 address this suite of approaches and provide an integrated approach to the "Is it food" question.

C. Contracts and Other Agency Assistance

Survey aircraft will be chartered from the private sector. Charter aircraft for surveys will not require contracts. ADF&G maintains a list of qualified air charter operators. Aircraft for surveys will be chosen from this list according to state procedures. Vessel support for tagging work will use small vessels contracts that will be completed by the Principal Investigator according the state SOP manual. Vessels will be chartered from the private sector.

Costs of acquiring SLTDR data from Service ARGOS are paid for through a contract with the National Oceanic and Atmospheric Administration (NOAA). This contract covers all ADF&G

Division of Wildlife Conservation satellite tagging projects (harbor and spotted seals, and caribou), not just this harbor seal restoration project, and is processed by the Division of Wildlife Conservation. Funds for data acquisition must be encumbered and guaranteed to NOAA in early February. Actual contract processing occurs later in the spring.

Satellite SLTDRs will be purchased under contract award from Wildlife Computers, a private company in Seattle, Washington. The contract award was negotiated in 1992 and will be active throughout the duration of this project. Wildlife Computers is the only company in the United States which manufacturers SLTDRs with the capabilities necessary to acquire the data we require about diving behavior of seals.

Fatty acid analyses and interpretation will be done by Dr. Sara Iverson at Dalhousie University through a Cooperative Agreement between ADF&G and Dalhousie. Dr. Iverson is the only person in North America with specific experience in analysis of fatty acids in seal blubber, and particularly with the sophisticated statistical analyses necessary to infer diet from the relative abundance of these fatty acids.

Genetics analyses will be done by Dr. Greg O'Corry-Crowe at the NOAA/NMFS Southwest Fisheries Science Center through a National Research Council fellowship. Dr. O'Corry-Crowe is currently working with ADF&G on harbor seal genetics studies in other parts of Alaska and can conduct additional analyses of PWS harbor seals at a very modest cost.

Other assistance and cooperative work towards accomplishing the objectives of this study are provided at no cost to the project by Dr. Randy Davis, Texas A & M University (physiological studies); Kate Wynne, University of Alaska Sea Grant Program (biological sampling and field assistance); Jon Lewis, ADF&G (NOAA-funded harbor seal studies in southeast Alaska and near Kodiak); and Dr. A. D. M. E. Osterhaus, National Institute of Public Health and Environmental Protection, Netherlands (phocine distemper and herpes assays).

D. Location

This project will be conducted in PWS. Aerial surveys will be flown over the 25 established trend count sites shown in Figure 1 and listed in Table 1. Seal tagging and sampling will take place at a variety of locations throughout PWS. Tagging locations will be chosen to represent different habitats and different proximity to areas oiled by the EVOS, and will be coordinated with sampling locations for oceanographic and forage fish studies. Communities that harvest harbor seals or engage in commercial fishing activities, and therefore may be affected by or utilize the results of this study, include Cordova, Chenega Bay, Tatitlek, and Valdez.

SCHEDULE

A. Measurable Project Tasks for FY 96 and beyond

This project will be conducted during 1996 and 1997, with submission of a final report in 1998. A schedule of field activities, data analysis, and report preparation follows:

1996-1997	
October - July:	Retrieve ARGOS data
October - December:	Analysis of fatty acid samples by Dalhousie
October - December:	Analysis of aerial survey data
October - September:	Analysis of genetic samples by SWFSC
October - April:	Analysis of other data, modeling
October - March:	Analyze SLTDR data from previous year
October - December:	Meet with hunters about study results, distribute newsletter
November - December:	Meet with SWFSC regarding genetics analyses
January:	Order SLTDRs for field season
January:	Attend restoration workshop
January or February:	Coordination meeting with other ADF&G harbor seal projects
January - April:	Arrange logistics (boats, airplanes, equipment, contracts, supplies)
February:	Reserve ARGOS satellite channels
February - March:	Prepare annual report
April 15:	Submit annual report
April-May:	Field work to catch seals and collect samples
June 7-20:	Conduct aerial surveys during pupping
June - August:	Analysis of fatty acid samples by Dalhousie
August 20-30:	Conduct aerial surveys during molting
September 15-30:	Attach 12 SLTDRs, sampling
1998	
January - September:	Final data analysis
October - December:	Prepare final report
December 30:	Submit draft final report

B. Project Milestones and Endpoints

April 15, 1996:	Report on modeling (Objectives 1.4, 4.3, 5.1, 5.2, 6.1, 6.2, 6.3)
April/May 1996, 1997:	Sampling seals in PWS (Objectives 2.1, 2.2, 2.3, 3.1, 7.1, 7.2)
June 1996, 1997:	Aerial surveys during pupping (Objectives 1.1, 4.1)
August 1996, 1997:	Aerial surveys during molting (Objectives 1.1)
April 15, 1996, 1997:	Annual report (Progress report objectives 1.2, 1.3, 2.1, 3.1, 3.2, 4.2,
September 1996, 1997:	Sampling seals in PWS (Objectives 2.1, 2.2, 2.3, 3.1, 7.1, 7.2)

September 1996, 1997:	Tag 12 harbor seals with SLTDRs (Objectives 1.2, 3.3, 7.7, 7.8)
Oct/Nov 1996,1997:	Meet with hunter representatives (Objectives 6.4)
December 1998:	Final Report (Objectives 1.5, 1.6, 3.2, 4.2, 7.3, 7.4, 7.5, 7.6, 7.9)

C. Project Reports

April 15, 1996:	Annual report for 1995 studies; will include results of pupping and molting surveys including trend analysis; multivariate analysis of factors affecting surveys; analysis of data for SLTDRs deployed in September 1994 and May 1995; report of 1995 modeling efforts; status report on 1995 fatty acid analyses; status report on genetics study
May 30, 1996:	Report of field activities for spring field work in PWS (letter form)
June 30, 1996:	Summary of pupping surveys flown during early to mid-June (letter form)
October 30, 1996:	Report of field activities for August surveys and September tagging
April 15, 1997:	Annual report for 1996 studies; will include results of pupping and molting surveys including trend analysis; analysis of data for SLTDRs deployed in September; report of 1996 modeling efforts; status report on 1996 fatty acid analyses; status report on genetics study
June 30, 1997:	Summary of pupping surveys flown during early to mid-June (letter form)
October 30, 1997:	Report of field activities for August surveys and September tagging
December 31, 1998:	Final report for 1995-1997 harbor seal restoration studies

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The project is part of an integrated MARINE MAMMAL ECOSYSTEM package. Other studies in the package include Condition and Health of Harbor Seals (Project 001, UAF); Harbor Seals and EVOS: Blubber and Lipids as Indices of Food Limitation (Project 117-BAA, UAF); and Comprehensive Killer Whale Investigation (Project 012, NMML). Although the study of Isotope Tracers - Food Web Dependencies in PWS (Project 320-I, UAF) is part of the PWS System Investigation, it will also be closely coordinated with this project and may be part of the Marine Mammal Ecosystem package in future years.

This project itself is a multidisciplinary, inter-agency undertaking. Surveys and satellite tagging will be conducted by ADF&G; lipid analyses and interpretation by Dalhousie University; blood chemistry analyses at UAF; genetics analyses by SWFSC/NMFS; and demographic modeling by NMML/NMFS. Inclusion of interdisciplinary components within the same project will ensure that data are shared and interpreted in an interdisciplinary manner.

This project (064) will provide logistics, the MMPA permit to conduct sampling, and access to seals and samples for all three PWS harbor seal projects. Archived harbor seal data and blubber samples will be provided to Castellini/UAF for use in analyses of body condition and blubber. Harbor seal investigators at ADF&G and UAF have been working successfully together for the last three years on

harbor seals in PWS and elsewhere, and future collaborations should be equally productive. Regular bi-weekly meetings and seminars are held by marine mammal investigators at UAF and ADF&G Fairbanks to exchange information and ideas.

This study will directly interface with the PWS System Investigation study entitled Isotope Tracers - Food Web Dependencies in PWS (Fish, Marine Mammals, and Birds). Samples of seal whiskers and seal prey have and will continue to be provided to that study. Investigators of the two projects (Frost and Schell/Hirons) discuss stable isotope results at regular intervals and are pursuing preparation and publication of a joint manuscript describing preliminary findings of this study.

Prey samples for fatty acid analysis will be obtained through PWS System Investigation studies and the APEX study. Species to be analyzed will be chosen based on their collective importance to harbor seals, seabirds, and killer whales. This project will work with project 121 to avoid duplicative analyses and to share data. Information on distribution and movements of harbor seals, and diving behavior, will be shared with PWS Sound Investigation modelling studies to look at energy flow within PWS, and with forage fish investigators who may examine the effects of predation on fish population dynamics.

This harbor seal study will obtain samples of prey and incorporate results from Herring (ADF&G) and Oceanographic (UAF) studies being submitted under the PWS System Investigation, and from the study Apex Predator Ecosystem Experiment. Harbor seal investigators will assist in prioritization of samples to be collected by Herring and Forage Fish studies for stable isotope and fatty acid analyses. Species to be analyzed will be chosen based on their collective importance to harbor seals, seabirds, and killer whales.

Harbor seal investigators are currently and will continue to participate in interactive discussions with subsistence hunters in PWS and the Gulf of Alaska through Project 244 (Seal and Sea Otter Cooperative Harvest Assistance) and through the newly formed Alaska Harbor Seal Commission. These discussions include the ongoing harbor seal decline, communication of results of Restoration-funded studies, suggestions for future research, and possibilities for local involvement in harbor seal investigations. The Subsistence Restoration Project - Food Safety Testing (Project 95279) has provided (and will continue to do so if it continues) samples to this harbor seal study for numerous analyses, including: genetics, stable isotopes, fatty acids, blood chemistry, and stomach contents.

This project is funded entirely by the Trustee Council as a restoration project. ADF&G conducts no other studies of harbor seals in PWS that are not a part of the restoration program. ADF&G has no management responsibility for harbor seals. The Subsistence Division of ADF&G has been funded by the Trustee Council to monitor the harvest of harbor seals in PWS (Project 244) and to conduct food safety testing (Project 279).

ADF&G 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 a stable population (southeast Alaska) of harbor seals. Equipment is shared by the two projects. Consequently, it has not been necessary for the PWS project to purchase many equipment items and supplies solely for the use of this study. Because of these other ongoing projects, the PWS harbor seal project has had access to a GIS system with which to analyze survey and tagging data.

ENVIRONMENTAL COMPLIANCE

NOAA has determined that this harbor seal study qualifies for categorical exclusion (CE) and does not require an environmental assessment, per a memo from Byron Morris, NOAA, dated 18 December 1992.

As required by the Marine Mammal Protection Act, ADF&G has been authorized under Permit No. 770 to instrument harbor seals with SLTDRs and to conduct a variety of sampling activities including collection of blood, whiskers, skin, and blubber biopsies. All MMPA permit applications are reviewed by federal agencies and the U.S. Marine Mammal Commission. They are available for review by state agencies and the public through a Notice of Receipt published in the Federal Register.

Site #	Description	Status relative to EVOS
1	Sheep Bay	unoiled
2	Gravina Island	unoiled
3	Gravina Rocks	unoiled
4	Olsen Bay	unoiled
5	Porcupine Point	unoiled
6	Fairmount Island	unoiled
7	Payday	unoiled
8	Olsen Island	unoiled
9	Point Pellew	unoiled
10	Little Axel Lind Island	unoiled
11	Storey Island	oiled
12	Agnes Island	oiled
13	Little Smith Island	oiled
14	Big Smith Island	oiled
15	Seal Island	oiled
16	Applegate Rocks	oiled
17	Green Island	oiled
18	Channel Island	unoiled
19	Little Green Island	unoiled
20	Port Chalmers	unoiled

21	Stockdale Harbor	unoiled
22	Montague Point	unoiled
23	Rocky Bay	unoiled
24	Schooner Point	unoiled
25	Canoe Passage	unoiled

Table 2. Harbor seals instrumented with SLTDRs and sampled during 1991-1994. Only SLTDRs from which significant amounts of data were received are included.

		SLTDRs							
Location	Date	AdM	SubM	AdF	SubF	DNA	Blood	Fat	Whiskers
Applegate Rocks	May 92		3	1			5		
	May 93	2				5	5		
	Sep 93						1	1	1
Bay of Isles	Sep 93	1				1	1		1
Channel Island	Sep 93	1				3	3		3
	Sep 94	2			1	13	11	13	12
Gravina Island	Sep 94		1			3	3	3	3
Green Island	Apr 94					1	1		1
Herring Bay	Sep 91			1			1		
Little Green Is.	Apr 94					1	1	1	1
Port Chalmers	Apr 94					2	2	2	2
	Sep 94			3	1	10	10	10	10
Seal Island	Apr 91						4		
	Sep 91	1					4		
	May 92						1	3	
	May 93	3		1		7	7		
	Sep 93	2	1	1		10	10		10
Stockdale Harbor	Apr 94					6	6	5	6
	TOTAL	12	5	7	2	64	78	34	60

Approved by TC 8/25/95 Version with changes (approved 12/11/95) in 1-29-96 memo from Wright/Rice/Cauls (cancel field work; fund close-out only)

HERRING REPRODUCTIVE IMPAIRMENT

Project Number:	96074
Restoration category:	Research
Proposer:	National Marine Fisheries Service
Lead Trustee Agency:	NOAA
Cooperating Agency:	State of Alaska, Department of Fish and Game, Division of Commercial Fisheries
Duration:	2 years
Cost FY 96:	**$140,000**
Cost FY 97:	**0**
Geographic Area:	Prince William Sound, and Southeast Alaska: includes laboratory research at Auke Bay, Juneau, Alaska
Injured Resource:	Herring

ABSTRACT

The purpose of this study is to examine the possibility of long term oil impacts on herring due to the *Exxon Valdez* oil spill using intense field and laboratory measurements. In FY 95, the study was partitioned into a field component (designed to search for possible reproductive impacts in PWS herring stocks caused by the *Exxon Valdez* oil spill) and a laboratory component (designed to determine if exposure of various life stages to oil can cause long term genetic damage), but in FY 96 only the field component will continue. This project was initiated in 1994 following the crash of herring populations in PWS, and represents the toxicological component of a suite of projects focused on causes of the crash and prospects for recovery.

INTRODUCTION

The 1993 crash in Prince William Sound herring resources stimulated a multi-disciplinary suite of studies to look at toxicological and ecological factors affecting long term recovery of the stocks. This proposal represents the toxicological part of an inter-agency herring package.

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* spill in PWS. Only a small proportion of fish from oiled areas showed significant histopathological damage in 1989 and 1990, but over 40% of the spawning areas were oiled (Brown et al. 1994). Many herring larvae collected from the water column exhibited morphological malformations, genetic damage, and small size that may have been caused by exposure to oil (Norcross et al. 199?), but when this damage was caused was not known (i.e., in pre-spawning adults, eggs, or larvae). Abnormal larvae were found as late as July, 1989 (Norcross et al. 1994), thus raising the possibility that abnormal larvae can survive for considerable periods of time (hatch in 1989 was in early May (Brown et al. 1994)), or that direct exposure of larvae to oil can lead to developmental

abnormalities. Exposure of herring eggs to petroleum hydrocarbon concentrations frequently results in abnormal larvae with poor survival potential (Kuhnold 1969; Linden 1976; Rosenthal and Alderdice 1976; Pearson et al. 1985; Kocan 1993). In the pectoral fins of herring embryos exposed to oil, anaphase aberrations were elevated (Hose et al. in prep.), giving some credence to the hypothesis that long term genetic damage was possible to the germ line. Some field research (Baker and Biggs, 1993; Kocan et al. 1994) suggests reproduction may have been impaired by previous exposure of adult or juvenile herring to oil in the water column, but with many uncontrolled (and unknown) factors, it is difficult to interpret these field data. Because year-class strength is heavily influenced by survival of herring larvae (Stevenson 1949; Taylor 1964; Outram and Humphreys 1974), contamination of pre-spawn adults, eggs, or larvae by petroleum hydrocarbons may have an adverse impact on herring populations.

Long term impacts remain a question, although immediate impacts were measured in the 1989-91 damage assessment studies. Recruitment failures appear to have continued and standing biomass has decreased; the toxicological influence of oil on either is unknown. The purpose of this study is to examine the possibility of long term impacts. Reproductively ripe adult herring will be collected from multiple sites in PWS, plus control sites in Southeast Alaska, and spawned by age class to determine if residual effects of the *Exxon Valdez* oil spill still persist in PWS stocks. Measurements include egg fertility, viability, and hatch timing, morphological abnormalities in the larvae and anaphase aberrations in the pectoral fins of larvae.

Time line. This four year project started in FY 94 with laboratory exposures to adult herring and impact measurements on larvae, and continued in FY 95 with direct exposure of incubating eggs to oil plus the first year of field observations. In FY 96, the oil toxicity laboratory studies will be closed out with a final report, and the field component will continue for a second (final) year. Table 1 gives the time line of the project.

Table 1

LABORATORY:

Year	Exposure	Measurement
FY94	pre-spawn adults	impacts on larvae
FY95	eggs	impacts on larvae
FY96	-	final report

FIELD:

Year	Exposure	Measurement
FY95	-	spawn viability by area and year class
FY96	-	spawn viability by area and year class
FY97	-	final report

Accomplishments in FY 94

In 1994 gravid adult herring were exposed to oil in water for a period of 8 or 16 days to determine the presence or absence of direct toxic effects, damage to gonads, reduced resistance to disease, and

heritable genetic damage in the progeny. Because it was not practical to measure germ line damage directly in the laboratory, efforts were focused on detection of chromosomal damage in the actively dividing somatic cells in the pectoral fins of larvae. Prediction of impacts on meiosis, therefore, was based on the premise that genetic damage in somatic cells would be correlated with germ line damage.

Exposure of gravid adult herring did not cause direct toxic effects to progeny, and gonads/gametes were not measurably damaged (as judged by egg fertility). Herring in this experiment were reproductively similar to those in PWS at the time of the *Exxon Valdez* oil spill. Arguably, gonads might be damaged if exposure had occurred earlier in maturation, such as at the time of gamete formation, but was beyond the context of the experiment. Resistance to disease in adults was decreased by exposure to oil, and mortality occurred in adults proportionate to oil dose. It is, therefore, plausible that disease resistance in herring populations in PWS was significantly reduced by exposure to oil, and that epizootics observed after exposure were an indirect manifestation of the spill. There was no indication that exposure of adult herring to oil caused chromosomal damage in somatic cells in progeny, and we infer that heritable genetic damage caused by exposure of adults was unlikely.

Accomplishments in FY 95

The FY 95 research and analysis is in progress. Adults were collected and spawned from seven sites (four within PWS and three in Southeast Alaska). Hatching was completed by mid June; tens of thousands of larvae were collected and will be examined in the next 4 months to determine size at hatch and abnormality rates. In the laboratory, two oil exposure experiments were completed: exposure caused premature hatch, reduced survival, and obvious morphological aberrations. When examination of preserved specimens is completed, we expect to confirm oil-induced increases in somatic chromosomal aberrations.

Proposal for FY 96

We propose to continue the field observational study for a second year to survey PWS herring stocks for evidence of reproductive damage caused by the *Exxon Valdez* oil spill. This will give two brood years of measurement for evaluation of long-term damage as expressed in reproductive impairment. We will close out the laboratory oil exposure part of the project with a final report.

NEED FOR THE PROJECT

A. Statement of Problem

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* spill in PWS. Major recruitment failures have occurred since the spill and standing biomass has decreased; the toxicological influence of oil on either is unknown. The standing stock in PWS crashed in 1993, thus herring are currently classified as not recovering. The stock crash in 1993 suggests the possibility that long term damage may have been a contributing factor in the crash or to lack of recovery. This study examines the toxicological basis for long term damage,

and seeks lingering evidence of such damage in Prince William Sound stock(s) by measuring reproductive impairment.

B. Rationale

The project will yield improved understanding of the impacts of the *Exxon Valdez* oil spill on the herring population in PWS, and add to the information base on the current status of reproductive fitness compared to other stocks. The monitoring portion of the study should continue in FY 96 before fish present at the time of the spill are all eliminated from the population through disease, predation, and senescence.

C. Summary of Major Hypotheses and Objectives

The goal of this study is to determine if herring reproduction in PWS stocks may have been impaired as a result of past oil exposures at one or more life stages. The primary test hypothesis is that fertility, percent hatch, larval viability, morphological abnormalities, and genetic aberrations were caused by the *Exxon Valdez* oil spill. These key reproductive parameters have been measured in 1995 and will be in 1996 from spawn taken from PWS and Southeastern Alaska control sites; multiple year classes will be sampled from each site. These key reproductive parameters have been measured in controlled laboratory oil exposures to adults and eggs in previous years.

D. Completion Date

Expected completion of the FY 96 field reproductive impairment research and report is April 15, 1997. The laboratory toxicology tests will be closed out and a final report submitted June 1, 1996.

COMMUNITY INVOLVEMENT

This project involves the collective local knowledge of the ADF&G employees living in Cordova and several towns in Southeast Alaska. Local hires have been and will be accomplished as needed to meet project goals.

PROJECT DESIGN

A. Objectives

Survey herring in PWS for reproductive impairment by measuring larval viability by location and age class. Herring reproduction may have been impaired as a result of past oil exposures at one or more life stages. This is a continuation of the survey begun in 1995 to 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. Additional eggs will be similarly collected and spawned from sites in Southeast Alaska as controls.

Primary test hypothesis: Fertility, percent hatch, larval viability, morphological abnormalities, and genetic aberrations were caused by the *Exxon Valdez* oil spill.

Assumptions: 1) The year classes prior to 1989 were potentially exposed to oil in 1989, 2) the 1989 year class was potentially exposed to oil in pre-spawning adults, eggs, and larvae, and 3) year classes after 1989 were not exposed to oil, except that the 1990 year class may have been exposed to residual oil in intertidal areas.

Controls will be post-spill year classes and two or three sites in Southeastern Alaska, including Sitka.

B. Methods

Observation requires extensive incubation of eggs, isolated by female, with monitoring for 30 to 40 days. We have the capacity to incubate eggs from approximately 950 individual females and will involve six technicians in addition to staff biologists at peak hatch. Some hatch staggering is possible, but spawning events are driven by reproductive condition of the fish and are site specific.

Procedures for collection, spawning, and transportation used in previous years will be followed. Reproductively ripe adult herring will be captured by cast net or gill net at four spawning sites in PWS and two with Southeast Alaska, separated by length into age classes, iced, transported to a laboratory facility, and spawned within 8 h of collection. Concurrent with our efforts at some sites, ADF&G will collect samples for age, weight, length, and disease. For age analysis, scales will be collected from each of 25 spawned females plus males providing milt. Ovarian membranes will be cut longitudinally and the eggs removed with a stainless steel spatula. From each female, eggs will be deposited on one 25 x 75 mm glass slides placed in seawater at the bottom of a shallow container. Approximately 100 eggs per slide will be deposited with gentle swirling. Eggs from each female will be placed in a staining rack and suspended in a beakers of seawater. Milt from 3 males will be prepared by cutting sections of testes into small segments. A few milliliters of milt will be added to beakers containing eggs. The eggs and milt will remain in contact 5 min. The eggs will be transported by air to Auke Bay in chilled seawater. Eggs will be suspended in seawater from monofilament line attached to arms driven by an offset cam to cause slow movement (1 rpm) through the water. Lighting will be natural, supplemented by overhead fluorescent light during daylight hours. Excess eggs will be removed from all slides by scraping, i.e., those along slide margins susceptible to mechanical damage, and clumps of eggs where not all eggs were exposed to water. This processing will be accomplished in water with a minimum of emersion. Eggs

will be counted to quantify fertilization success and stage development will be noted. Approximately one week before hatch, eggs from each female will be isolated in 1000 m l glass jars; slides will be held with plastic clamps and suspended with monofilament line from a mobile overhead rack. Jars will be placed in a flowing seawater bath. Hatch timing, hatching success, larval viability, and larval abnormalities will be observed daily for each fish. Hatched larvae will be assessed for swimming ability and gross morphological deformities. Larvae from each female will be preserved in buffered formalin for genetic analysis. Preserved collections will be arranged to group the first 10% of the hatch, the majority of larvae, and the last 10% of the hatch by female parent. Dead eggs and embryos will be quantified at the end of hatch.

Age classes from each location that could have been exposed to oil will be compared to those that were not: e.g., 1985-1989 vs 1990 (maybe trace oil or residual oil on beaches?) vs 1991-1993, and oiled locations will be compared with those that were not. Analysis of Variance techniques will be used to determine significance.

C. Contracts and other Agency Assistance

The primary plan to collect fish is to cooperate with ADF&G at the time each herring fishery occurs. However, as a contingency, it may be necessary to contract some commercial vessel time. For this purpose, $6,000 has been requested for boat charters.

As in previous years, the genetic analysis will be contracted. The purpose is to search for cellular damage and chromosomal aberration in a manner consistent with previous *Exxon Valdez* oil-spill related herring research, including this project.

D. Location

Prince William Sound (PWS), Sitka Sound, and Auke Bay Laboratory (ABL). Herring impairment samples will be collected in PWS and in Southeast Alaska. All egg incubation will be at ABL.

SCHEDULE

A. Measurable Project Tasks for FY 96

1995 brood year: finish analyses and reports.	Mar 1996
1996 Brood year:	
1. reproductive impairment survey in PWS:	Feb - Jun 1996
2. Chemical and contract analyses:	Jul - Nov 1996
3. Data analysis and final report:	Dec 96 - Apr 97

B. Project Milestones and Endpoints

Collection of data from live herring will be completed by July 1996: genetic and chemical analyses will

continue for approximately four months thereafter. Data analysis will require three months, and report writing an additional two. The FY96 project should be complete in April 1997.

C. Project Reports

A project report will be completed by April 1997. It is our intent to publish our data in peer-reviewed journals.

COORDINATION AND INTEGRATION OF RESTORATION 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. This project is a continuation of project 94166 and 95074 and is part of an inter-agency cooperative study with ADF&G; it is the toxicological part of the 'Herring Package'. The other ADF&G/SEA plan projects are focused on the current status of the population and other factors that may limit recovery, including disease. Researchers from ABL will work closely with ADF&G to collect fish; age, length, weight, and VHN samples will be simultaneously collected from the same sites and year classes that reproductive impairment samples are collected, thus integrating state and federal research objectives.

ENVIRONMENTAL COMPLIANCE

EA or EIS are not required by this project.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Office of Oil Spill Damage Assessment and Restoration
P.O. Box 210029
Auke Bay, Alaska 99821

January 29, 1996

MEMORANDUM FOR: Molly McCammon

FROM: Bruce Wright, Jeep Rice, and Mark Carls

SUBJECT: Revisions to 96074 DPD

Project 96074, as originally funded, was designed to complete a second season of observations of reproductive condition of herring stock(s) in Prince William Sound, and to complete data acquisition, analysis, and report writing from projects 94166 and 95074. This reproductive impairment project was initiated in 1994 with an expected duration of 3 research years plus one year to complete data analysis and the final report. Milestones for the project to date include 1) exposure of adult herring to oil and observation of resultant progeny in 1994, 2) exposure of incubating herring eggs to oil in 1995, and 3) survey of reproductive success of Prince William Sound herring stock(s) by female age, including sites in southeastern Alaska as controls.

Analysis of the field data was essentially complete by December, 1995. There were no discernable indications of effects of the *Exxon Valdez* oil spill, and we recommended that a second year of field observations would not be necessary to address the original question of lingering oil impacts. Bob Spies, Chief Scientist, concurred with this conclusion, therefore we proposed reducing the funding from $200k to $140.

By canceling the field-related logistics and contracted processing labor, $60K was released back to the Trustees, and there will be no closeout costs in FY97. We will retain some contracted labor to finish analyses of 1995 data and writing, but there will be no charges for contribution of the NMFS principle investigators (Rice, Carls, and Short). The NMFS contribution will remain at $111.0K.

Close-out activities include completion of data collection, data analysis, and report writing. From the 1995 research, acquisition of three data sets is currently incomplete; hydrocarbon analysis, morphometric assessment, and length measurements. Completion of outstanding data is necessary before the final report can be completed. Morphometric assessment should be completed by approximately mid March; the other data sets will be completed earlier. Allowing three additional months for completion of analysis and writing, the final report will be completed June 15, 1996.

Expected close-out expenditures primarily include salary for two biologists (77.7K) and contracts for sample and data processing plus data analysis (40.0K). Remaining amounts are for expendable commodities (3.8K), travel (4K), and general administration (13.8K).

The final report will contain all data from 1994 and 1995 research, including exposure of adult herring to hydrocarbons, MFO induction, disease response in adult fish, effects of indirect oiling on progeny, effects of incubating eggs in oil-contaminated water, and assessment of the reproductive condition of Prince William Sound herring stock(s) in 1995. Because completion of the final report is expected within two months of the required annual report, we request the annual report be waived in lieu of the final report.

Although published manuscripts are not part of the required reporting process, the message has been received. Based on projects 94166, 95074, and 96074, we anticipate production of the following manuscripts:

Thomas, R. E., M. G. Carls, S. D. Rice, and L. Shagrun. In prep. Mixed function oxidase induction in pre- and post-spawn herring (*Clupea pallasi*) by petroleum hydrocarbons.

Carls, M. G., D. E. Hinton, G. D. Marty, T. R. Meyers, S. D. Rice, and R. E. Thomas. In prep. Disease, mortality, and bioaccumulation of hydrocarbons in pre-spawn herring (*Clupea pallasi*).

Carls, M. G., D. Fremgen, J. E. Hose, D. Love, and R. E. Thomas. The impact of exposure of adult pre-spawn herring (*Clupea pallasi*) to weathered crude oil on subsequent progeny.

Carls, M. G., D. Fremgen, J. E. Hose, S. W. Johnson, and S. D. Rice. Effects of incubating herring (*Clupea pallasi*) eggs in water contaminated with weathered crude oil with particular emphasis on morphological and genetic abnormalities.

Johnson, S. W., C. C. Brodersen, M. G. Carls, B. Stone, and S. D. Rice. Reproductive impairment of herring (*Clupea pallasi*): comparison of populations exposed to oil in Prince William Sound to populations not exposed to oil in Southeast Alaska.

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

Project Number:	96076
Restoration Category:	Research
Proposer:	Alex Wertheimer and Stanley Rice NMFS, Auke Bay Laboratory
Lead Trustee Agency:	NMFS
Duration:	4 years
Cost FY96:	$393.8
Cost FY97:	
Cost FY98:	
Cost FY99:	
Geographic Area:	Little Port Walter, Baranof Island, Southeast Alaska
Injured Resource:	Pink salmon

ABSTRACT

This project examines the effects of oil exposure during embryonic development on straying, marine survival, and gamete viability of pink salmon. The primary objectives are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil and other factors on straying so that field studies of straying in PWS after the spill can be interpreted, and to evaluate the significance of straying on management and restoration strategies.

INTRODUCTION

This project will examine the effects of oil exposure during embryonic development of pink salmon on the straying, marine survival, and gamete viability of returning adults. A series of controlled experiments will determine the impact of oil exposure on straying, as well as the effects of other factors (marking, stock, and transplant), so that measurements of straying in PWS after the spill can be interpreted, and the significance of straying on management and restoration strategies can be evaluated.

The project will require tagging several hundred thousand fry from wild and experimental treatment groups over two brood years, and examining returning adults in natal streams, other streams within 50

km of the natal streams, and an adjacent fishery. Pink salmon will be collected and spawned, and the fertilized eggs will be incubated in a controlled simulation of oiled intertidal habitat which occurred in Prince William Sound (PWS) after the *Exxon Valdez* oil spill. Fry from the oil-exposed and control groups will be marked to identify treatments when they emigrate from the incubators, and then released to migrate to the Gulf of Alaska. Corresponding groups of wild fry will also be captured and marked. Recoveries of tagged adults will be used to determine if oil exposure causes differences in straying and marine survival. Escapement and sampling rates in natal and non-natal streams will be estimated so that actual straying rates within the sampling region can be estimated, and the effects of oil, marking, population, and geographic factors on straying rate can be evaluated. Adults from the oil-exposure experiments that return to the release site will be identified as to treatment and then spawned. The fertilized eggs will be incubated in a clean environment to determine if oil exposure had affected gamete viability of fish from the original treatment groups.

This is a large multi-year study requiring significant logistic support for operations at remote sites. The study will be located in southeast Alaska because of the possible influence of prior or continuing oil contamination of pink salmon in PWS. The project was initiated in FY95 and will extend over five years. The incubation array for oil exposure is now under construction. Adults from the 1995 and 1996 returns will be collected and spawned in September of each year, and the fertilized eggs will then be placed in the experimental incubators (FY 95/FY96). In the spring of 1996 and 1997 (FY96/FY97), fry from the oil-exposed and control groups will be marked to identify treatments and released to migrate to the Gulf of Alaska; corresponding groups of wild fry will also be captured and marked. In the fall of 1997 and 1998 (FY97/98, FY98/99), adult returns will be sampled in natal and non-natal streams and in a large nearby fishery to recover marked fish from the experimental groups. Adults from the oil-exposure experiments returning to their release site in 1997 and 1998 will be spawned, and the survival of their progeny to the fry stage will be determined (FY98, FY99). Annual reports will be prepared each year. A final report will be prepared in 1999 summarizing the results of the study and the analysis of the restoration objectives. A synthesis of the results with previous field studies on pink salmon straying in PWS will also be prepared to evaluate the impacts of oil on straying of pink salmon, and to assess the implications of straying to management and restoration strategies for pink salmon in PWS.

NEED FOR THE PROJECT

A. Statement of Problem

Pink salmon were injured at several life-history stages during and shortly after the oil spill. Evidence of long-term damage from the toxic exposures of 1989 continues to build, and a thorough evaluation of the toxic contribution to pink salmon recovery problems became even more important when there was no explanation for the crash in pink salmon and herring in 1993. Three areas of continuing concern are the impacts of oil exposure on (1) homing and straying behavior; (2) survival of emergent fry in the marine environment; and (3) reproductive viability of exposed fish and their offspring.

Straying was a major concern during the spill; the Trustees supported a multi-million dollar effort to assess straying, and substantial straying of wild and hatchery stocks was observed. Unfortunately, the interpretation of that study is severely limited for several reasons. Consequently, the amount of straying

caused by oil is not known, natural straying rates are not known, and straying information cannot be used to develop or adjust restoration or management strategies.

B. Rationale

Pink salmon will be considered recovered when populations are healthy and productive and exist at pre-spill levels of abundance. Understanding the toxic effects of the 1989 oiling is a major component of the Trustee Council's program to restore pink salmon. This project contributes to the recovery of pink salmon by determining if oil exposure during incubation influences straying, marine survival, and gamete viability.

Results from Natural Resource Damage Assessment and Restoration Studies following the spill indicate that the toxic exposures of 1989 have caused persistent, long-term damage to pink salmon. Field studies in PWS after the *Exxon Valdez* oil spill have demonstrated differences in embryo survival between oiled and non-oiled streams. In addition, laboratory studies have shown that differences in survival between oiled and non-oiled streams are heritable (Restoration Study 94191A). Long-term (7-8 months) intra-gravel exposure of developing pink salmon eggs and alevins caused retarded development, altered emergence timing, decreased survival to eyeing and emergence, and an increased occurrence of gross lesions at emergence; it also had the surprising effect of delayed impacts on marine growth (Restoration Study 94191B). These developmental abnormalities from exposure to oil could persist and affect the behavior and fitness of the fish during subsequent life-history stages, including: (1) homing and straying; (2) survival of emergent fry in the marine environment; and (3) reproductive viability of exposed fish and their offspring.

Straying of pink salmon was a major issue following the spill. The Trustees supported a multi-million dollar effort to assess straying, and substantial straying of wild and hatchery stocks was observed. The ability of salmon to home (to return to their natal stream to spawn) is probably the most well-known and remarkable characteristic of these fish. Not all salmon return to their natal stream, however; some stray to non-natal streams to spawn. Some degree of straying is important to salmon populations; it is a mechanism for colonization of new habitat, as well as for the recolonization of habitat that has been damaged and subsequently restored. However, disruption in the normal amount of straying could have adverse impacts on the genetic structure of locally-adapted salmon populations. If high straying rates for pink salmon occur naturally in PWS, then the genetic structure of the populations in PWS should be relatively homogeneous, and large-scale mixing of wild stocks and the hatchery stocks derived from them should be of minor concern. Restoration of damaged pink salmon runs would thus be expected to occur naturally through recolonization from healthy stream systems. However, if the presence of oil increased straying from normally low levels, then the genetic diversity among and within wild stocks could be jeopardized from induced straying, and the genetic damage hypothesized to occur as a result of incubation in oiled substrate could be passed on to pink salmon in streams originally not oiled by the *Exxon Valdez*.

Straying rates for wild pink salmon observed in PWS in 1991 averaged 26% and ranged from 8-54% for fish from both oiled and non-oiled streams, based on coded-wire tag (CWT) recoveries in natal and non-natal streams. These straying rates seem high in relation to the concept that salmon normally home Unfortunately, interpretations of that research are confused because even the wild stocks from non-oiled streams (controls) had to pass through oiled areas, and were thus not true controls. Also, marking the

fish with CWTs may have affected their straying behavior. Normal levels of straying are not known for pink salmon. Consequently, the amount of straying caused by oil is not known, and straying information cannot be used to adjust restoration or management strategies. This study will conduct controlled straying experiments to permit an evaluation of oil on straying, and to examine the effect of tagging, stock, and transplant on straying. To avoid the confounding effects of prior or continuing exposure to oil, the experiments need to be carried out in a geographic region remote from PWS. By identifying the effects of the various factors on straying, however, the results of these experiments can be directly applied to interpret the previous straying study in PWS.

C. Summary of Major Hypotheses and Objectives

The primary objectives of this study are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil exposure of pink salmon embryos on their subsequent straying as adults; determine the role of other factors on straying so that the measurements of straying in PWS after the spill can be interpreted; and evaluate the significance of straying on management and restoration strategies in PWS. The study will also examine the effect of oil exposure during egg and alevin development on subsequent marine survival and gamete viability of pink salmon. Specific hypotheses to be tested include:

1. Oil exposure during embryonic development increases the straying of pink salmon.
2. Coded-wire tagging of pink salmon fry increases straying.
3. Stock origin (upstream vs. intertidal) affects the straying rate of pink salmon.
4. Transplant of gametes from a stream to a hatchery incubation and release site affects the straying rate of pink salmon.
5. Oil exposure during embryonic development decreases marine survival of pink salmon.
6. Oil exposure during embryonic development decreases the gamete viability of pink salmon

D. Completion Date

This project will extend over the entire life-history of two brood years of pink salmon and will also include the egg/alevin life-history stage of their progeny. Oil exposures and marking of experimental groups will be completed by 1997. Recovery of returning adults will be completed by 1998. Evaluation of the viability of gametes of returning adults will be completed by 1999. The final report summarizing the results and detailing the accomplishment of the project's restoration objectives will be submitted in 1999.

COMMUNITY INVOLVEMENT

Scientists involved in this study will regularly present progress reports and results in scientific and public forums, including the annual workshop They will be available to talk with interested public and will provide information for Trustee Council newsletters and annual reports as appropriate.

This project will be located in southeast Alaska out of the spill area because of the need to avoid the confounding effects of previous or continuing oil contamination in PWS. However, it will require substantial labor for fish marking and stream surveys, as well as contracts for vessel charters. Agency

hiring restrictions may limit us to contract hires for the intensive labor needs. We anticipate soliciting contract hires from communities in the area of the study (Juneau, Sitka, Petersburg, and Port Alexander) We encourage the Trustee Council to develop a labor pool from local communities in the spill area from which individuals could be either contracted or hired directly through the Council Administration for this and other Restoration projects. This would provide spill area residents better opportunity to participate directly in Restoration research.

PROJECT DESIGN

Pink salmon were injured at several life-history stages during and shortly after the oil spill. Evidence of long-term damage from the toxic exposures of 1989 continues to build, and a thorough evaluation of the toxic contribution to pink salmon recovery problems became even more important when there was no explanation for the crash in pink salmon and herring in 1993. Straying was a major concern during the spill; the Trustees supported a multi-million dollar effort to assess straying, and substantial straying of wild and hatchery stocks was observed (Sharp et al. 1995). Unfortunately, the interpretation of that study is severely limited for several reasons. Consequently, the amount of straying caused by oil is not known, natural straying rates are not known, and straying information cannot be used to adjust restoration or management strategies. This project contributes to the understanding of the toxic effects of the oil spill and to the recovery process by examining the effects of oil exposure during incubation on the straying, marine survival, and gamete viability of pink salmon.

After the unexpected crash of pink salmon in 1993, two major research thrusts emerged: (1) evaluation of the ecosystem and its ability to support recovery of populations (SEA plan); and (2) evaluation of long-term damage from earlier oil exposure. Long-term damage was not originally suspected, even though there was ample evidence of short-term damage such as reduced embryo survival (Bue et al 1995), reduced marine growth (Wertheimer and Celewycz 1995; Willette 1995), and population effects (Geiger et al. 1995). Bue et al. (1995) found that elevated egg mortalities continued in oiled streams beyond the initial years of heavy oiling in intertidal spawning zones. They hypothesized that these persistent effects resulted from heritable damage passed on to subsequent generations. One model of how oil contamination could cause this damage is based on the biology of pink salmon egg-alevin development: Pink salmon spawn in contaminated intertidal zones of streams; the embryos incubate in contaminated streams for 7-8 months; and oil, which is extremely lipophillic, is readily absorbed into the large yolk reserves of the embryos. This exposure then causes both lethal and non-lethal damage to

developing embryos. The non-lethal damage can result in subtle developmental changes with potentially large implications in later life history stages, such as reduced marine survival and increased straying.

This model of exposure and damage is supported by controlled laboratory exposures to pink salmon eggs at Little Port Walter (LPW). This research, stimulated by the ADFG field studies, has shown that long-term (7-8 months) intra-gravel exposure of developing pink salmon eggs and alevins caused the predicted short-term effects (retarded development, altered emergence timing, decreased survival to eyeing and emergence, an increased occurrence of gross lesions at emergence) and also had the surprising effect of delayed impacts on marine growth (Restoration Study 94191B). These developmental abnormalities from exposure to oil could persist and affect the behavior and fitness of the fish during subsequent life-history stages, including: (1) homing and straying; (2) survival of emergent fry in the marine environment; and (3) reproductive viability of exposed fish and their offspring.

Substantial straying was observed in PWS after the oil spill in 1991 in a large tagging effort of both wild and hatchery pink salmon (Sharp et al. 1995). Interpretations of the study are confused because of concern that tagging caused some of the straying (pers. comm., J. Seeb, ADFG, Anchorage), and because even the wild stocks from non-oiled streams (controls) had to pass through oiled areas and were thus not true controls. Normal levels of straying are not known for pink salmon, and so it is difficult to evaluate the consequences of the observed straying. This study will conduct controlled experiments to permit an evaluation of the effects of oil incubation, tagging, stock, and transplant on straying. To avoid the confounding effects of prior or continuing exposure to oil, the experiments need to be carried out in a geographic region remote from PWS. By identifying the effects of the various factors on straying, however, the results of these experiments can be directly applied to interpret the previous straying study in PWS.

Straying rates for wild pink salmon observed in PWS in 1991 averaged 26% for fish from both oiled and non-oiled streams, based on coded-wire tag (CWT) recoveries in natal and non-natal streams (Sharp et al. 1995). Straying was highly variable, ranging from 8% to 54% for the six wild populations marked; straying rates were higher on average for wild fish than for hatchery fish. These high straying rates were surprising, but interpretation and use of the data were severely limited for several reasons. First, natural straying rates for pink salmon are not known for PWS or other areas. Second, the "controls" were wild stocks from non-oiled streams, but these fish had to migrate along contaminated shores, and were not true controls. Thus no measure of normal rates exists. Furthermore, if oil contamination continues, or heritable damaged was indeed passed on, then "normal" rates cannot now be measured in PWS. Third, concern exists that placing CWTs in small pink salmon fry may cause damage responsible for some or most of the straying. Consequently, while substantial straying was measured in both oiled and non-oiled areas, clear interpretation of the results is not possible, and the significance of the measured straying remains unknown.

Straying rates of 26% seem high in relation to the concept that salmon normally home. However, virtually no other quantitative information exists on straying rates of wild pink salmon in their natural range for comparison. Reported straying rates in other species of salmon are highly variable. Examples are: Labelle (1992) observed an average straying rate of 2% for five stocks of wild and enhanced coho salmon, with a range of 0-11%; straying rates tended to be lowest for hatchery fish and highest for stocks subjected to certain supplementation practices Pascual and Quinn (1994) reported highly precise homing of hatchery chinook salmon to the Columbia River, even if the fish were transplanted into the river.

However, straying within the river was extremely variable among hatcheries, ranging from 1% to 95%, and was influenced by both environmental and genetic factors (Pascual and Quinn 1994). Tallman and Healey (1994) measured the straying rates for chum salmon in two streams located 2 km apart in the same bay; the straying rate from Walker Creek to Bush Creek was around 50%, while the straying rate from Bush Creek to Walker Creek was less than 2%.

The ability of salmon to home (to return to their natal stream to spawn) is probably the most well-known and remarkable characteristic of these fish. This tendency permits the establishment of discrete, locally adapted populations which are the basis of the stock concept in salmon management (McDonald 1981) Not all salmon return to their natal stream, however; some stray to non-natal streams to spawn. Straying is in itself a highly adaptive behavior. It is a mechanism for the colonization of new habitat (Milner and Bailey 1989), as well as for the recolonization of habitat that has been damaged and subsequently restored (Roys 1971; Leider 1989). Alexanderdottir (1987) and Quinn (1984) have speculated that pink salmon, which do not have overlapping generations because of their two year life cycle, may have relatively high rates of straying to provide a spatial population structure as a buffer against the risks inherent in a fluctuating environment.

The occurrence of strays in a spawning population does not necessarily mean that the strays are successful in transferring genetic information into the population. Tallman and Healey (1994) found that the gene flow was substantially lower than the straying rate among three populations of chum salmon, suggesting that strays have lower reproductive success than the native fish. However, higher gene flow was associated with higher straying rates. The rate and pattern of straying can still be considered indicative of the potential level of genetic interaction among populations and of the capacity of the species for recolonization of a site (Pascual and Quinn 1994).

Three possible explanations have been proposed for the high rates of straying observed for pink salmon in PWS. One is that oil exposure of the embryos induced high straying. No information exists on whether the developmental abnormalities associated with such exposure could also include deterioration of imprinting and homing. Previous research on the effects of oil on straying has focused on exposing returning adult salmon to oil for a short period of time (1-2 hours). Short-term exposure to oil had no deleterious effect on homing of either chinook salmon (Brannon et al. 1986) or coho salmon (Nakatani et al. 1985). Short-term oil exposure did cause temporary disorientation in migrating adult pink salmon but did not prevent the eventual return to the home stream (Dames and Moore 1989). Straying rates observed in PWS by Sharp et al. (1995) were similar for fish from both oiled and non-oiled streams, however, the results were confounded because fry from non-oiled streams may have been exposed to oil as they migrated along oiled beaches.

The second explanation is that CWTs contributed to the observed straying rates. Morrison and Zajac (1987) reported that improperly injected CWTs can damage the olfactory nerves of small chum salmon Pink salmon fry are smaller than chum salmon fry, and thus may be more easily damaged by tag injection Seeb (pers. comm., ADF&G) found that many of the tags from pink salmon that had strayed in PWS were not in the ideal location in the head.

The third explanation is that the straying rates observed were indeed representative of wild stocks in PWS. Sharp et al. (1995) speculated that pink salmon originating from the intertidal reaches of streams may not imprint as strongly as do pink salmon spawned in upstream reaches of a stream, and may thus

return to a general region rather than a specific stream. Up to 75% of pink salmon spawning in PWS is in intertidal stream reaches. Pascual and Quinn (1994) also found that chinook salmon released into tributaries to the estuary of the Columbia River had higher straying rates than did the same group of fish released from locations higher upstream, suggesting that longer migration time or distance in freshwater may improve imprinting and homing.

The degree of straying of wild pink salmon is an important issue in the restoration and management of wild pink salmon populations in PWS. Information on the spatial patterns of straying, and the factors that affect them, can have direct bearing on such issues as the genetic interaction of wild and hatchery stocks (Pascual and Quinn 1994). If high straying rates occur naturally, then the genetic structure of the populations in PWS should be relatively homogeneous, and large-scale mixing of wild stocks and the hatchery stocks derived from them should be of minor concern. Restoration of damaged pink salmon runs would thus be expected to occur naturally through recolonization from healthy stream systems. However, if the presence of oil increases straying from normally low levels, then the genetic diversity among and within wild stocks could be jeopardized from induced straying, and the genetic damage hypothesized to occur as a result of incubation in oiled substrate could be passed on to pink salmon in streams originally not oiled by the *Exxon Valdez*.

The primary goals of this study are to conduct a related series of controlled experiments on straying of pink salmon to determine the role of oil and several other factors on straying so that the measurements of straying in PWS after the spill can be interpreted; and to evaluate the significance of straying on management and restoration strategies

A. Objectives

This project has six major objectives related to straying of pink salmon. The design also permits evaluation of two additional objectives concerning the effects of oil exposure during incubation on marine survival and gamete viability.

1. Determine if oil exposure during incubation affects straying of pink salmon.
   Hypothesis: Oil exposure during embryonic development increases the straying of pink salmon

2. Estimate natural straying rates of two stocks of pink salmon. Accomplishing this objective requires a sampling program that can estimate the total strays within a specific geographic area, and evaluation of the influence on straying of such factors as tagging, stock, and transplant (Objectives 3-6).

3. Determine if coded-wire tagging of pink salmon fry affects straying rate.
   Hypothesis: Coded-wire tagging of pink salmon fry increases the straying of pink salmon

4. Determine if stock type affects the straying rate of pink salmon.
   Hypothesis:. Stock origin (upstream vs intertidal) affects the straying rate of pink salmon

5. Determine if first-generation transplant affects the straying rate of pink salmon.
   Hypothesis: Transplant of gametes from a stream to a hatchery incubation and release site affects the straying rate of pink salmon

6. Develop a synthesis of pink salmon straying research, including the results of this study and use it to evaluate the implications for management and restoration strategies.

7. Determine if oil exposure during incubation affects the marine survival of pink salmon fry
Hypothesis:. Oil exposure during embryonic development decreases the marine survival of pink salmon.

8. Determine if oil exposure during incubation affects the gamete viability of pink salmon
Hypothesis: Oil exposure during embryonic development decreases the gamete viability of pink salmon.

B. Methods

Overview

This project has been designed to examine the effects of oil exposure during embryonic development of pink salmon on: 1) straying rate, 2) marine survival, and 3) gamete viability of returning adults. Pink salmon gametes will be taken from fish returning to Lovers Cove Creek, an intertidally-spawning population on southeast Baranof Island (Figure 1). The embryos will be incubated at Little Port Walter (LPW) near the terminus of Sashin Creek in a controlled simulation of oiled intertidal habitat which occurred in PWS after the *Exxon Valdez* oil spill. Fresh water and salt water for incubation will be provided from Sashin Creek and the LPW estuary, respectively. Fry will be tagged with CWTs to identify treatments (Table 1, Objectives 1, 7, 8) and released to migrate to the Gulf of Alaska. Returning adults will be recovered at the release site, from the AKI hatchery brood stock return, and at other streams within 50 km of the release site. The cost-recovery fishery at AKI hatchery will also be sampled as a proxy for the commercial fishery. Recoveries of tagged adults will be used to determine treatment-specific straying rates and marine survival. Tagged adults returning to the release site will be held and spawned, and the fertilized eggs will be incubated in a clean environment to determine gamete viability of fish from the original treatment groups. The experiment will be conducted on two brood years (1995 and 1996) of pink salmon.

Because the effects of oil incubation on straying may be confounded by other factors that could affect straying, the influence of CWTs, stock, and transplant on straying will also be experimentally tested These comparisons will utilize wild fry emigrating from both Sashin Creek and Lovers Cove Creek, as well as pink salmon fry from the control group of the oil-exposure experiment. The CWT effect will be examined by comparing straying rates of two groups of CWT fry with similar fish marked with fin clips only (Table 1, Objective 3). The stock effect will be tested by comparing straying rates of Sashin Creek wild emigrants and Lovers Cove Creek wild emigrants (Table 1, Objective 4). The transplant effect will be tested by comparing straying rates of Lovers Cove Creek wild emigrants with the control group of the oil-exposure experiment (Table 1, Objective 5). These comparisons will also be repeated for both brood years.

Sampling design: Assumptions and power

Assumptions. An empirical model was developed to determine the power to detect differences in straying between oil-exposure treatment groups at the release group sizes and sampling regimes proposed A

number of assumptions were necessary to simulate the numbers of strays available for recovery, including marine survival, effects of oil exposure and marking and tagging on survival, straying rate, and sampling rate in non-weired streams.

Survival rates to return were based on the historical weir records for Sashin Creek (Olsen and McNeil 1967; Vallion et al. 1981). Survival to the weir ranged from 0.2 to 23.1%, averaged 3.7%, and had a median of 1.6% for 31 years for which data are available during the period 1939-1980. Because the distribution of survivals was highly skewed, the median was used as the assumption for "normal" survival An estimate of 0.9% was used for "low" survival; over 70% of the observed survivals for Sashin Creek wild fry have been greater than or equal to this value.

Marking fish can be expected to reduce survival. No literature value is available for the effect of the CWT on small pink salmon. However, Bailey (1995) found that chum salmon fry marked with the adipose fin clip and CWT had 50% lower survival than unmarked fry. This rate includes the effects of tag loss subsequent to release. We used this as an adjustment to the survival assumptions, which gives a range of 0.5-0.8% survival to the weir. Wild pink fry marked with CWTs at Auke Creek, Alaska, for four brood years averaged 2.2% survival to return to the Auke Creek weir, with a range of 0.8-3.8% (Mortensen 1991). Our assumptions on survival are conservative relative to these observations

Exposure to oil may also reduce marine survival (Hypothesis 2), which could affect our ability to detect differences in straying between treatments. We tested two levels of reduction in our survival assumption due to effects of oil: 20% and 50%.

The same survival rate was also assumed for adipose/pelvic fin-clipped fish. Although Blankenship (pers comm., L. Blankenship, Washington Dept. Fish., Olympia, Wash.) observed lower survival for pelvic fin-clipped coho and chinook salmon smolts than for adipose fin-clipped, CWT smolts, Bailey (1995) observed higher survival for chum salmon fry with only pelvic fin clips and fish with both adipose and pelvic fin clips compared to adipose fin-clipped, CWT chum salmon fry. At Sashin Creek weir, returns of pink salmon marked with pelvic fin clips in 1976 ranged from 2.9 to 4.8% (Vallion et al. 1981).

We used two estimates of straying rates to project the numbers of strays that will be produced. The low rate (7%) was based on the observed rate of straying of hatchery pink salmon in the Juneau area (pers comm., L. Macauley, Douglas Island Pink and Chum Salmon, Juneau). The high rate (26%) was the average observed in PWS by Sharp et al. (1995).

Based on the observations of stray pink salmon in PWS, we assume that the number of strays will decline with increasing distance from the natal stream. Sharp et al. (1995) recovered 79% of their total strays 30 km or less from the natal stream. We used this figure to estimate the number of strays that will be available in pink salmon streams within approximately 30 km from LPW, and developed a sampling design to intensively sample fish in streams within this distance. We assume that strays will be distributed proportionately to the escapement within this 30-km area. More distant sites will also be sampled, but at a lower effort.

Sampling effort will be allocated to four strata, with effort and methods varying between strata (Table 2) Stratum 0 includes streams with existing weirs where all returning fish can be sampled. Stratum 1 includes other pink salmon streams within 20 km of Sashin Creek, and Stratum 2 included streams 20-30

km from Sashin Creek. In strata 1 and 2, we assume we could sample at least 50% of the return as carcasses. Escapement to these streams will also be estimated to provide a measure of sampling fraction. This will allow expansion of tag recoveries to estimate actual number of strays to the surveyed streams, and will us to check our assumption of sampling rate. Stratum 3 includes streams 35-50 km from LPW. These streams will be sampled for tag occurrence rate only, to examine the assumption of declining occurrence with distance. Specific streams selected are listed in Table 3.

Streams were selected for sampling within Strata 1 and 2 based on the relative magnitude of the escapements within the sampling area. An index of escapement was generated using ADFG peak escapement counts from aerial surveys. The peak counts were expanded by a factor of 2.5 (from Sharr et al. 1993) to account for counting bias relative to the exact counts at the traps in Stratum 0. Based on this index, the streams selected provide >90% escapement coverage within the 30 km sampling region (Table 2). For stratum 3, one pink salmon stream was selected for sampling in each of the large bays occurring within 35-50 km of LPW. The specific stream selected was the one with the largest escapement within a particular bay, so that the number of carcasses checked will be maximized.

Power of sampling design. We ran simulations of the model predicting number of strays recovered, using the different combinations of survival, straying, and fishery exploitation estimates. Preliminary runs showed that the optimal number of CWTs per oil-exposure treatment was 70,000, given the limitations on the minimum number of treatment groups and the number of fry that could feasibly be marked (Table 1). Logistics of the wild fry marking limited treatment groups of wild fish to 60,000.

Simulations were then run to determine what level of difference between a dose and control could be detected with 95% confidence at the tagging and sampling levels proposed. Strays were assumed to be recovered only from strata 0-2 (30 km sampling region).

Results of the simulations showed that the magnitude of increase in straying detected is sensitive to the assumptions of survival and the straying rate of the controls (Table 4). At the median survival and low straying rate for the control, a 75-100% increase in straying (from 7% to 12-14%) can be detected, depending on the reduction in the marine survival of the treated group. At low survival and low straying for the control, a 100% increase in straying can be detected if the treated group has a 20% reduction in marine survival. At a 50% reduction in marine survival, the probability of detecting 100% increase declines to 94% (Table 4). For high straying rates, a 50% increase (from 26% to 39%) can be detected under all survival assumptions.

The ability to detect differences in marine survival under these same assumptions was also evaluated. We could consistently detect a 20% decrease in marine survival (from 0.8% to 0.6% or 0.5% to 0.4%) at the tagging and sampling levels proposed.

Gamete collection, egg incubation, and fry marking

Pink salmon gametes will be collected in the fall of 1995 and 1996 from Lovers Cove Creek, Baranof Island, southeastern Alaska. Ripe adult pink salmon will be seined from Lovers Cove Creek, and gametes from 245 females and 245 males will be collected and transported to the nearby NMFS research station at Little Port Walter (LPW) to be spawned. A randomized embryo pool will be created by: 1) spawning the

females into a common container, 2) randomizing the eggs within the container, 3) dividing the eggs into 245 aliquots, 4) fertilizing each aliquot with an individual male, and 5) recombining all fertilized eggs into a composite embryo pool. This composite embryo pool will then be divided into 92 aliquots of approximately 4000 eggs each. Each aliquot will then be randomly assigned to one of four treatments. high exposure dose, intermediate exposure dose, a control group to be marked with CWTs, and a control group to be marked with an adipose and left pelvic fin clip. A total of 92,000 eggs (23 aliquots) will be needed for each group. The individual aliquots will be incubated in individual pipe incubators filled with gravel.

Instream incubation will be simulated in the pipe incubators. These incubators will be constructed from 30-cm long sections of 20-cm diameter polyvinyl chloride pipe. The pipe will be stood on end, sealed, and fitted with a water intake at the bottom. The pipe will then be filled with appropriately-treated gravel. This design will allow water to upwell through the gravel and then out through an outlet fitting at the top of the incubator pipe. Fertilized eggs will be laid on top of the gravel to incubate. Upon hatching, the alevins will be permitted to burrow into the substrate.

Starting 24 hr after fertilization, embryos will be exposed to salt water for 4-hour intervals every 12 hours to simulate an intertidal environment. Water supply to the incubators will flow from a large head tank During saltwater exposure periods, salt water with 26-30 parts per thousand salinity will be pumped from the bay into the head tank. At the end of each saltwater exposure cycle, saltwater flow into the head tank will be shut off, and freshwater flow into the head tank will be resumed. Salinity will thus rise and fall gradually at the beginning and end of each saltwater treatment period.

Dosing levels in the oil treatments will be based on the results from Restoration Study 94191B. Actual dosing will be established by analyzing hydrocarbon concentrations with gas chromatograph and mass spectroscopy (GC/MS) in incubator effluent and substrate at the beginning of the experiment and in incubator effluent, substrate, and fish tissue at each major developmental stage: eyeing, hatching, and emergence.

Various parameters will be recorded during incubation. Survival to eyeing and emergence, size at emergence and release, and emergence timing will be measured for each treatment group.

Upon emergence, fry will be moved to separate estuarine net pens for each treatment group to be held for tagging and fin-marking. Marking will begin as soon as sufficient fish (~ 10%) have emerged. In the spring of 1996 and 1997, a total of 210,000 pink salmon fry (70,000 per exposure treatment) from the gravel incubators will have their adipose fin removed and be coded-wire tagged (Table 1, Hypotheses 1-3). An additional 70,000 fry will be marked by removing the adipose fin and the left pelvic fin (Table 1. Hypothesis 1A). Approximately 10,000 fry can be marked daily.

Marking will be stratified into seven time periods to randomize the effects of handling and time of release. For each time stratum, a subgroup of 10,000 fry will be marked from each of the four experimental groups in a random sequence Fry from all four subgroups within a stratum will be released at the same time, approximately 64 hr after the fourth subgroup is marked. Tag placement and clip quality will be checked regularly throughout each marking day. Subsamples for tag retention for each CWT subgroup will be taken after 24 and 48 hr Mortalities following marking will be assessed daily

until the fish are released. A composite group of 2000 fish will also be held for 14 days to monitor tag retention and mortality; these fish will not be released.

Capture and Tagging of Wild Fry.

Wild pink salmon fry emigrating from Sashin Creek and Lovers Cove Creek in 1996 and 1997 will be captured, marked, and released (Table 1, Hypotheses 1A, 1B, 1C). In Sashin Creek, fry will be captured using a floating screw trap. In Lovers Cove Creek, fry will be captured with screw traps or fyke nets. Capture methods for this component of the study will be tested in Spring 1995 to determine the most effective technique. From each stream, 60,000 fry will be tagged with CWTs in code lots of 10,000 tags (Table 1, Hypotheses 1B,1C). At Sashin Creek, an additional 60,000 fry will be marked by removing the adipose fin and the right pelvic fin (Table 1, Hypothesis 1A). Equivalent numbers of fry will be CWT and pelvic fin-clipped at Sashin Creek on a given day. Fish will be held in pens adjacent to the traps for 64 hr. Tag placement and clip quality will be checked regularly throughout each marking day. Subsamples for tag retention for each CWT subgroup will be taken after 24 and 48 hr. Mortalities following marking will be assessed daily until the fish are released. Historical data from Sashin Creek show that emigration timing is highly variable, and can extend from early April until early June (Olsen and McNeil 1967), requiring an extensive trapping period to ensure sufficient coverage. From 2-4 people will be required at each site, depending on the number of fish to be handled and marked. Up to 3000 fry per day will be CWT at each stream.

Adult recoveries

Stream Recoveries. To assess the rate of homing vs. straying behavior, returning marked pink salmon will be recovered from natal and non-natal streams on Baranof Island and Kuiu Island (Figure 1) Sampling effort will be structured in four strata, with effort and methods varying between strata (Table 2). The sampling period will extend from mid-August through mid-October in 1997 and 1998.

Stratum 0 is comprised of the weir on Sashin Creek and the AKI hatchery brood stock raceway at Jetty Lake Creek in Port Armstrong. Close to 100% of the fish returning to these locations will be sampled The expected returns to these streams represent 44% of the index escapement within 30 km of Sashin Creek (Table 2).

AKI Hatchery personnel will be contracted to examine all pink salmon that enter the facility and are spawned, in order to identify and recover strays from the various treatment groups. Any fish with a missing adipose fin will be retained for scanning for CWT and missing pelvic fins.

All pink salmon entering Sashin Creek will be checked for missing adipose fins. The weir will be operated so that fish cannot leave after entering, in order to provide a precise count of the number of fish in the creek. Fish with adipose fins will be passed into the creek. Fish without adipose fins will be checked for a missing pelvic fin. Pink salmon entering Sashin Creek that are missing a pelvic fin will be counted and killed. If both pelvic fins are present, the fish will be placed in a pen and held until mature for spawning for the gamete viability experiment. At that time, the fish will be killed, scanned for a tag, and the tag removed and decoded (if present). A CWT fish will be considered to have homed to Sashin Creek, unless the fish is from the Lovers Cove wild fry group

Stratum 1 is comprised of pink salmon streams sampled within 20 km of Sashin Creek. All these watersheds will be on the east coast of Baranof Island (Figure 1). The streams sampled in this stratum represent 16% of the total escapement within 30 km of Sashin Creek (Table 2). Escapement of the sampled streams will be estimated to determine sampling proportion.

A three-person crew based at LPW will check carcasses on each of the streams once per week, with the exception of Lovers Cove Creek, which will be checked 2-3 times per week over a 6 week period. The streams will be accessed from LPW using a 5.1-m Boston Whaler skiff. The higher effort at Lovers Cove Creek is an attempt to sample as high a proportion of the escapement as feasible, because of the need to provide a precise estimate of both strays from the treatments released at LPW, and of homing fish from the Lovers Cove Creek wild fry. Each carcass will be counted, checked for a missing adipose fin, and marked with a jaw tag. The jaw tag will identify on subsequent surveys that the carcass has been already examined for marks. The jaw tag is also a critical component of the escapement estimation technique for each stream, described below. If a fish is missing the adipose fin, the head and the pelvic girdle (with fins attached) will be removed for later scanning for the presence of a CWT or a pelvic fin clip.

Stratum 2 is comprised of pink salmon streams approximately 20-30 km from Sashin Creek. These include watersheds on the east coast of Baranof Island and the west coast of Kuiu Island (Figure 1). The 30-km arc does not intersect all of Tebenkof Bay on Kuiu Island. Tebenkof Bay has four major embayments. We included in Stratum 2 streams in those embayments (Piledriver Cove and Thetis Bay) that are intersected by the 30-km arc, even if the streams were slightly (< 3km) east of the arc. The streams sampled in this stratum represent 30% of the total index escapement within the 30-km sampling region (Table 2). Escapement of the sampled streams in Stratum 2 will be estimated to determine sampling proportion.

A four-person crew based on a charter vessel will survey each of the streams once per week over a six week period. The vessel-based operation will allow safe transit of Chatham Strait to sample streams in Tebenkof Bay, Port Malmesbury, and Patterson Bay (Figure 1). The crew will be able to sample during the day, then move safely to the next location after completing a survey.

Stratum 3 is comprised of pink salmon streams approximately 35-50 km from Sashin Creek. These include watersheds on the east and west coast of Baranof Island, and on the west coast of Kuiu Island The stream with the largest ADFG escapement index count in each of five bays will be sampled Red Bluff Bay, Rowan Bay, Bay of Pillars, Gut Bay, Branch Bay, and the inner portion of Tebenkof Bay If time permits, streams in Table Bay on southwest Kuiu Island and Puffin Bay on southwest Baranof Island will also be surveyed (Table 3). The survey crews will not attempt to estimate escapement for these streams (with one exception); the emphasis will be on checking carcasses for tags and tag occurrence rate as a check of the assumption that stray recovery rate is proportionate to distance from natal stream It may be possible, however, to get a rough estimate of sampling proportion using ADFG aerial survey counts for streams on which escapements were estimated, and generating an average expansion factor for the sampling year for the aerial surveys.

These streams (with the exception of Alecks Creek in Tebenkof Bay) will be sampled once per week over a three week period by a four person crew operating from a support vessel. The NOAA vessel R/V John N. Cobb will be used if available; otherwise it will be necessary to charter. The vessel-based operation will permit safe transit of Chatham Strait and the outer coast of Baranof Island to access sampling sites

The survey crew can sample during the day, then travel in the vessel afterwards to be in position for the next day's survey. During the survey, the crew will count and examine as many pink salmon carcasses as possible for a missing adipose fin. If a fish is missing its adipose fin, the head and the pelvic girdle (with fins attached) will be removed for later scanning for the presence of a CWT or a pelvic fin clip. The tail will be cut off of carcasses with adipose fins so that they can be identified on subsequent surveys as having been previously examined .

Alecks Creek in Tebenkof Bay will be sampled by the crew responsible for Stratum 2. Because this crew will already be sampling in the outer portion of Tebenkof Bay, this will be logistically efficient. Also, Alecks Creek is by far the largest stream in Tebenkof Bay, representing 30% of the peak escapement counts; no other stream has more than 10%. For this reason, Alecks Creek represents a good opportunity to determine if escapement magnitude or distance from natal stream influences occurrence of strays. Carcasses will be jaw-tagged for a population estimate for Alecks Creek in order to estimate sampling fraction on this system.

Tag Location. The location of CWTs within the heads of returning adult pink salmon will be examined to determine whether straying was influenced by where the tag was placed within the snout. Heads from adipose fin-clipped adults will be X-rayed so that tag location in fish that stray can be compared with tag location in fish that home. Samples of up to 100 heads will be X-rayed from each of three recovery categories: Sashin Creek, Lovers Cove Creek, and other area streams. The samples from Lovers Cove Creek and the other area streams will be from spawning or spawned-out fish. At Sashin Creek, however, because all adipose fin-clipped fish returning to the weir will be held alive after capture, and the tag will be removed and decoded at spawning in order to identify the treatment group, only fish that die in the holding net prior to spawning will available to X-ray for tag location.

Estimation of Escapement. To estimate escapement into the stratum 1 and 2 index streams we propose to use the modified Jolly-Seber technique for carcass counts provided by Sykes and Botsford (1985) This population size estimator assumes an open population, and is relatively insensitive to violations of the assumptions of age-dependent catchability and survival (in our case, catchability and survival refer to the detectability and persistence of the carcasses over time). Standard errors are provided by simulation Surveys of index streams will include recovering heads and ventral fins from adipose clipped fish, counting the number of carcasses in the stream, marking a representative fraction of the carcasses with snap ties, and noting the number of carcasses marked with snap ties on subsequent visits. The escapement to Sashin Creek in 1995 will be estimated using this technique and compared to weir counts This initial analysis provides an opportunity to develop the simulation software prior to the first escapement surveys in 1997 and will produce an estimate of variance so designs for future escapement surveys can be refined.

Fisheries Recoveries

The number of fish harvested in the commercial fishery is not critical to our estimates of marine survival and straying if the assumed survival rates are representative of post-fishery survival, and if the treatment groups are equally distributed in the fisheries. However, if oil does affect homing behavior, then exposed groups might mill around more and thus be differentially vulnerable to the fishery. Pink salmon returning to Sashin Creek are thought to enter Chatham Strait from the south (Hoffman 1982). Adult tagging

studies indicate that some Sashin Creek fish move up Chatham Strait as far as Frederick Sound before returning to their natal stream. Fish harvested in lower Chatham Strait, however, are exclusively of lower Chatham origin (Hoffman 1981). Over the last four years, pink salmon harvest in area 109 from Frederick Sound to Cape Ommaney has averaged 17 million fish (pers. comm., H. Savikko, ADFG, Juneau). Fishery exploitation of Sashin Creek pink salmon is thought to be around 30% (pers. comm., Ben Van Alen, ADFG, Juneau). We estimate that the tag incidence rate for each treatment would be 1 in 30,000-50,000 fish in the general harvest area.

Because sampling this large and widely-dispersed fishery would be expensive and difficult, we propose instead to sample the AKI Hatchery cost-recovery fishery as a proxy for the common property fishery. Projected harvest for this fishery is 1,000,000 pink salmon (pers. comm., Dana Owens, Armstrong Keta Inc., Juneau). We can reasonably expect to cost-effectively sample at least 30% of this harvest to test whether treatment groups were exposed to differential harvest rates. No estimate of the power of the test is possible. Although fish harvested in lower Chatham Strait are predominately from the local area, we do not know if the cost-recovery harvest is representative of the general seine fishery in lower Chatham Strait. We propose to sample this fishery in 1997 (1995 brood returns) and use the results to (1) test for differential harvest of oil-exposed groups and (2) determine exploitation of Sashin Creek fish in the harvest. This information can then be used to determine the power of the sample to detect differences between treatments. Based on these results, and the geographic pattern of strays recovered by treatment, we can reconsider the option of broader fishery sampling in 1998 (1996 brood return).

At this time, AKI plans to deliver its fish to a floating processor located near the hatchery (pers. comm., Dana Owens, Armstrong-Keta Inc., Juneau). Sampling this harvest will require arranging with the processor to permit two samplers to examine pink salmon and remove those with a missing adipose fin as the fish are delivered to the processing lines. The samplers will be housed at Port Armstrong or on the processor for the duration of the harvest (3-4 weeks); heads and pelvic girdles from fish with missing adipose fins will be picked up and taken to LPW for examination for tags and fin clips and tag recovery and decoding at least twice weekly.

Analysis of Straying and Survival

The G-test of independence (Sokal and Rohlf 1981) will be used to test for statistical differences (P = 0.05) in straying between treatments for the oil-exposure and tagging-effects experiments (Objective 1,3). The number of strays observed in all escapement sampling strata and the number of homing fish recovered at Sashin Creek weir will be compared between treatments. For the oil-exposure test (Objective 1), if a significant difference is detected between the three groups, all three possible paired comparisons will be made, with the rejection criterion adjusted for multiple comparisons so that overall P = 0.05. For the effect of tagging experiment (Objective 3), two two-way contingency tables comparing the CWT and fin-marked releases will be analyzed.

Comparisons of straying rates between Lovers Cove Creek wild fish and Sashin Creek wild fish (Objective 4), and Lovers Cove Creek wild fish and transplanted Lovers Cove Creek fish (Objective 5) cannot be tested with the G-test because we will not have a complete count of the number of homing fish at Lovers Cove Creek. The total homing to Lovers Cove must be estimated by expanding observed tags by the sampling fraction. Comparisons for these objectives must thus be made using the estimated straying rates and associated variances, rather than observed recoveries.

Straying rates will be estimated for the various treatment groups by estimating the total number of strays, S, in non-natal streams within the 30-km sampling region, and the total number of homing fish, H, in the natal stream (Objective 2). S is calculated by

$$S_j = (\Sigma s_{ij}) / p,$$

where s_{ij} is the estimated number of strays for a particular treatment, j, in each non-natal stream surveyed, i, and p is the proportion of the escapement sampled within 30 km. Each s_{ij} is the observed number of strays expanded for the proportion of the escapement sampled for tags in stream i. H is the count of homing fish to Sashin Creek for all treatments, except Lovers Cove Creek wild fish; in that case, H is the observed number of homing fish in Lovers Cove Creek, expanded for the proportion of the escapement sampled for tags. The straying rate, f, is then

$$f_j = S_j / (S_j + H_j).$$

The variance of this proportion can be calculated from the variances of S and H. For S,

$$\text{var}(S_j) = \Sigma \text{var}(s_{ij}).$$

The variance of each s_{ij} is derived from the variance of the escapement estimate used to calculate the proportion sampled for tags in stream i. For H, var(H) = 0 for Sashin Creek, because H is a total count At Lovers Cove Creek, the variance of H is also derived from the variance of the escapement estimate used to calculate the proportion sampled. Variance of f is then

$$\text{var}(f_j) = [H^2(\text{var}(S)) + S^2(\text{var}(H))]/(S + H)^4.$$

A linear logistic model will be used to describe the relationship between straying rates and various factors, following the model used by Labelle (1992) for coho salmon. The objective is to predict the probability of straying for particular combinations of treatment, population, and geographic factors The model used is

$$E[S/(S+H)] = \exp(b_0 + b_1 x_1 + b_2 x_2 + \ldots) / [1 + \exp(b_0 + b_1 x_1 + b_2 x_2 + \ldots)]$$

where f is the frequency of straying, b_n are parameters estimated by the model, and x_n are the predictor factors. We will use oil treatment, mark type, stock, transplant, distance from natal stream, direction from natal stream, and magnitude of non-natal stream as predictor factors.

Effects of oil exposure on marine survival (Objective 7) will be tested using the G-test. The contingency table for the comparison will be a 2 x 3 table, comprised of the three groups and the number of survivors and non-survivors for each group. The number of survivors for a treatment will be the sum of the observed number of tags at Sashin Creek weir, the observed number of tags recovered as strays, and the observed number of tags in the AKI fishery. The number of non-survivors for a treatment will be the number of "good" tags released (the number of fish tagged for a treatment adjusted for tag retention) minus the number of survivors. If a significant difference is detected between the three groups, the three possible paired comparisons will be made, with the rejection criterion adjusted for multiple comparisons so that overall $P = 0.05$.

h. Reproductive viability

Gamete viability will be determined for the oil treatment groups and the control (Objective 8). Tagged adults captured at Sashin Creek weir in 1997 and 1998 will be held for spawning. The CWT will be removed and decoded at spawning to identify the oil-treatment groups. Fish from each oil dose and from the control will be mated using a fully-crossed half-sib design (Falconer 1981). In this design, eggs from an oil-exposed female and a control female are each split into two aliquots. One aliquot from each female is fertilized with aliquots of sperm from the same oil-exposed male, and one aliquot from each female is fertilized with aliquots of sperm from the same control male. This 2 x 2 breeding matrix will be replicated 30 times for each treatment. Each half-sib family will be incubated in an individual container. Survival will be measured to fertilization, eyeing, and emergent fry stages. The numbers of defective or dead progeny will be compared between treatment groups. Because these gametes will not be incubated in an oiled environment, any observed increases in mortality or defective individuals can be attributed to oiling effects upon the first generation.

This approach will test if oil exposure lowers embryo survival, and will allow partitioning of the effect due to the male and female components. This will extend the results from Restoration Project 95191B, which will test for differences in gamete viability between within-treatment groups. Results obtained from the 1997 returns will be used to review and refine the breeding design in 1998.

C. Contracts and Other Agency Assistance

Personnel for the tagging and stream crews will be hired by contract. The AKI Hatchery will be contracted to screen their returning adult pink salmon for any tagged pink salmon from this study that have strayed to their facility. Contracts for vessel charters may be needed to transport crews to recover returning adult pink salmon from streams more than 30 km from LPW.

D. Location

The project will be implemented at Little Port Walter (LPW, Figure 1), a research facility of the NMFS Auke Bay Laboratory (ABL). This location is appropriate because of the logistic and infrastructure support the ABL and the LPW station provide for this complex array of experiments. It is also necessary to examine the response of pink salmon straying to oil exposure at a geographic locale remote from PWS, away from the confounding effect of prior or continuing oil exposure. Gametes will be collected from Lovers Cove Creek and Sashin Creek, Baranof Island, southeast Alaska. Eggs will be incubated, and pink salmon fry will be tagged at LPW, near the mouth of Sashin Creek, 10 km from Lovers Cove Creek Returning adult pink salmon will be recovered from streams on the eastern coast of Baranof Island within 50 km of LPW.

Technical support provided at this location includes the use of the research station at LPW as a base for the 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 ABL will provide four tagging machines, vessel support, computer services, analysis of GC/MS samples, and communication and administrative support Materials and personnel will be transported to and from LPW via the NOAA vessel R/V John N Cobb, as well as contracted air taxi charters.

SCHEDULE

A. Measurable Project Tasks for FY 96

September to March:	Incubate fertilized embryos (1995 brood); collect 36 GC/MS samples Develop contractual labor agreements for tagging operations; evaluate fertility, early embryo survival in incubator.
March:	Install traps for collection of wild fry (1995 brood)
March-April:	Evaluate survival in incubators to fry emigration
April:	Annual report
April-May:	Tag and release hatchery and wild fry (1995 brood)
June:	Clean incubators
July:	Set up incubators for 1996 brood
August:	Oil gravel
September:	Collect and spawn pink salmon (1996 brood); Incubate fertilized embryos (1996 brood); Collect initial GC/MS samples (8) from incubator effluent and substrate

B. Project Milestones and Endpoints

Milestone	Completion Date
Spawning of 1995 brood adults	Sep 1995
Oil exposure of 1995 brood embryos	Apr 1996
Marking of 1995 brood fry	May 1996
Spawning of 1996 brood adults	Sep 1996
Oil exposure of 1996 brood embryos	Apr 1997
Marking of 1996 brood fry	May 1997
Spawning of 1997 brood adults	Sep 1997
Recovery of 1995 brood marked fish	Oct 1997
Estimation of 1997 natal, non-natal stream escapements	Oct 1997
Determination of 1997 brood gamete viability	Apr 1998
Spawning of 1998 brood adults	Sep 1998
Recovery of 1996 brood marked fish	Oct 1998
Estimation of 1998 natal, non-natal stream escapements	Oct 1998
Determination of 1998 brood gamete viability	Apr 1999

Endpoints

1. Objective 1: Determine if oil exposure during incubation affects straying of pink salmon
   Completion Date: **January 1999**

2. Objective 2: Estimate natural straying rates of two stocks of pink salmon. Accomplishing this objective requires a sampling program that can estimate the total strays within a specific geographic area, and evaluation of the influence on straying of such factors as tagging, stock, and transplant (Objectives 3-6).
Completion Date: **January 1999**.

3. Objective 3: Determine if coded-wire tagging of pink salmon fry affects the straying rate of pink salmon.
Completion Date: **January 1999**.

4. Objective 4. Determine if stock type affects the straying rate of pink salmon.
Completion Date: **January 1999**.

5. Objective 5. Determine if first-generation transplant affects the straying rate of pink salmon
Completion Date: **January 1999**.

6. Objective 6. Develop a synthesis of pink salmon straying research, including the results of this study, and use it to evaluate the implications for management and restoration strategies.
Completion Date: **September 1999**.

7. Objective 7. Determine if oil exposure during incubation decreases the marine survival of pink salmon fry.
Completion Date: **January 1999**.

8. Objective 8. Determine if oil exposure during incubation decreases the gamete viability of pink salmon.
Completion Date: **July 1999**.

C. Project Reports

Annual progress reports will be submitted in April of 1996, 1997, 1998, 1999.

1996 annual report: Details of the spawning of adult pink salmon in September, 1995, and the incubation of embryos (1995 brood).

1997 annual report: Details of the tagging and release of pink salmon fry (1995 brood), analysis of 44 GC/MS samples (1995 brood); the spawning of adult pink salmon in September, 1996; and the incubation of embryos (1996 brood).

1998 annual report: Details of the tagging and release of pink salmon fry (1996 brood); analysis of 44 GC/MS samples (1996 brood); the recovery and spawning of adult pink salmon (1995 brood) in September and October, 1997; and preliminary analysis of straying rates and marine survival of the 1995 brood.

1999 annual report: Details of the recovery and spawning of adult pink salmon (1996 brood) in September and October, 1998; and preliminary analysis of straying rates and marine survival of the 1996 brood and gamete viability of the 1995 brood.

The final report will be submitted in September, 1999.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Research by NMFS on effects of oil exposure to pink salmon has been closely coordinated with concurrent research efforts by ADF&G and UAF. This project directly complements Restoration Study No. 95191B and will be fully coordinated with its continuation.

per TC action 12-11-95

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service amends OPD
Office of Oil Spill Damage
Assessment and Restoration
P.O. Box 210029
Auke Bay, Alaska 99821

January 3, 1996

Ms. Molly McCammon
Executive Director
Exxon Valdez Oil Spill Trustee Council
645 G Street Suite 402
Anchorage, AK 99501

Re: Changes in Projects 96076 and 96191B

Dear Molly:

This letter is to provide you with an overview of the changes made to Projects 96076 and 96191B. Originally, 191B had a "placeholder" budget, because it was unknown what the returns in September 1995 would be. As it turned out, the returns were better than expected, and continuing the project was well supported because of the continuing oil effects observed. As you know, we proposed to combine these projects in the November Pink Salmon reviews in Anchorage and to reduce the temporal scope of 96076 in order to greatly reduce the costs of the research, while still maintaining our primary scientific objectives. The budget approved by the Trustee Council at its December meeting was for the reconfiguration of the two projects, at the levels we proposed and covered at the November meetings. This letter follow up confirms the reconfiguration, confirms the final report for 191B. and the budgets approved and required to accomplish these projects.

Project 96191B- This project will be closed out in FY- 1996. The project will complete the evaluation of gamete viability of 1993 brood year pink salmon (P-1 fish) exposed to oiled incubation substrate by monitoring the survival of progeny (F-1) of these fish to the fry stage. After final evaluations of the F-1 progeny (size, survival, timing of emergence), which will be completed after emergence in April 1996, the fry from control and treated groups will be tagged in the spring of 1996 and released. The Final Report for 191B will be completed by November 1, 1996, and will include extensive review of the P-1 results (direct exposures), from egg to adult, and will contain the results to date of the F-1 (no direct exposures), from egg to fry release.

The next phase of the 191B research, the gamete viability of the F-1 fish, will be evaluated as part of the 076 research in 1997 and 1998. If sufficient numbers of F-1 fish return, their reproductive viability will demonstrate whether exposure of the P-1 fish caused heritable genetic damage. We will be working with quantitative geneticists from UAF JCFOS to design the F-1 breeding experiments, which would start at the end of FY 97, and carry over into the front half of FY 98.

Project 96076- The major change to this project was to eliminate the exposure, tagging, and recovery of the 1996 brood year pink salmon. Thus the project will involve a single (1995) brood year of pink salmon. It retains the objectives of examining the effects of oiled incubation substrate on straying and survival to spawning; it utilizes 076 fish to reexamine, at higher resolution, the impact of oil exposure on subsequent reproductive viability; and it retains the objectives of examining the effects of stock, transplant, and tagging on straying. The basic design of the project remains the same other than the elimination of the 1996 brood. We did make a change in the implementation plan based on the results of the 1995 field work and recovery of strays returning from Project 95191B. We increased the amount of effort planned in 1997 for sampling strays and estimating escapements for surveyed streams within approximately 30 km of the natal watershed. We hope to better refine the sampling strategy for both streams and local fisheries in the 1997 DPD in consultation with Dr. Mundy and ADFG scientists.

This revision of the two projects reduces the projected FY 96-99 costs from $2,271.0 K as originally proposed in the 1996 Work Plan to $1,408.0 K, for a savings of almost $900 K (see table below). We do lose the ability to look at interannual variation in straying and survival under this configuration. However, we thought this loss was worth the substantial savings, as we do retain our original scientific objectives. Under this scenario, we can continue the promising enquiry into the damage caused by the exposure of pink salmon embryos to oiled incubation substrate. The series of experiments at Little Port Walter have already yielded some extraordinary results on the effects of oil on the embryo survival, subsequent growth, and reproductive viability of pink salmon. The straying component will determine if oil was a factor in the high straying rates observed in PWS following the oil spill, and provide insight into factors influencing homing and straying of wild pink salmon populations. Information on the spatial patterns of straying, and the factors that affect them, have direct bearing on such issues as the genetic interaction of wild and hatchery stocks and restoration management strategy.

Summary of Budget Changes for Projects 191B and 076.
($ Thousands)

	Original Proposals			Revised Proposals		
Fiscal Year	191	076	Combined	191	076	Combined
1996	169	394	563	160	394	554
1997	120	715	835	0	619	619
1998	88	525	613	0	235	235
1998	0	260	260	0	0	0
Total	377	1894	2271	160	1248	1408

Please let us know if you need more information on these projects prior to the Annual Reports and 1997 Detailed Study Plans. The December federal government furloughs have caused considerable logistics nightmares with our Little Port Walter operation, and have caused an inordinate amount of frustration and adrenalin flow. Keeping Little Port Walter functioning during this period has been our highest priority.

Sincerely,

Jeep Rice for AW

Alex Wertheimer
Principle Investigator

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Herring Bay Monitoring and Restoration Studies / Close out

Project Number:	96086
Restoration Category:	Monitoring
Proposer:	University of Alaska
Lead Trustee Agency:	ADF&G
Duration:	1 October 1995 - 30 September 1996
Cost FY96:	$173,000
Geographic Area:	Herring Bay, Knight Island, PWS
Injured Resource/Service:	Intertidal Invertebrates and Algae

ABSTRACT

In 1990, intertidal restoration studies were established in Herring Bay, Prince William Sound in response to the *T/V Exxon Valdez* oil spill. These studies have continued through the 1994 field season and show continued injury to *Fucus gardneri* and associated invertebrate populations, especially in the upper intertidal. The data collected during the 1995 field season will be incorporated into the existing Herring Bay data base and the rates and extent of recovery determined for injured resources.

INTRODUCTION

The Herring Bay Experimental and Monitoring studies conducted from 1990 through 1994, and continuing through the 1995 field season, showed damage to the intertidal invertebrate and algal population. Significant differences were detected between oiled and reference sites for grazing invertebrates such as *Tectura persona, Lottia pelta,* and *Littorina sitkana* and for the primary space competitor and main structural component of the upper intertidal, the alga *Fucus gardneri*. Recovery is under way in lower and middle intertidal zones and normal community interactions are returning. The upper intertidal, however, continues to exhibit damage. Data collected during the 1995 field season will allow estimates of the rates and extent of recovery in the upper intertidal. In addition, methods for actively enhancing *Fucus* recovery in severely damaged areas were tested and have been successful in reducing desiccation rates which may lead to increased germling survival. The evaluation of the erosion control fabric will continue through 1995.

NEED FOR THE PROJECT

A. Statement of the Problem

Five years after the Exxon Valdez oil spill, several intertidal species are still showing damage, including *Fucus*, the important structural component of the intertidal ecosystem. Monitoring of key intertidal species in Herring Bay will continue through the 1995 field season. However, additional funding is required to analyze these data and incorporate them into the existing Herring Bay data base, which will allow estimates of the degree and rates of recovery of injured species.

B. Rationale

Intensive research has shown that recovery subsequent to the oil spill is incomplete, especially for *Fucus* and associated invertebrate populations in the upper intertidal elevations. Populations of several key invertebrate and algal species will be monitored during the FY95 field season, requiring sample and data analysis. Funding is requested in FY96 for sample and data analysis and for the completion of the final report following the 1995 field season.

C. Summary of Major Hypotheses and Objectives

The objective of this study is to estimate the rates and extent of recovery of injured invertebrates and algae in the intertidal zone of Herring Bay. These results will be submitted in a complete report on the FY95 field season studies.

D. Completion Date

This work will begin in October 1995 and be completed in June 1996.

COMMUNITY INVOLVEMENT

This project will utilize University of Alaska personnel previously involved in Herring Bay Monitoring and Restoration Studies. They have extensive experience with these field and laboratory studies. The final report will be available to the public through the OSPIC office in Anchorage.

PROJECT DESIGN

A. Objectives

The overall objective of the study is to determine the rates and extent of recovery of injured resources in Herring Bay, especially of *Fucus* in the upper intertidal. This will be accomplished through the analysis of data collected during the 1995 field season for invertebrate abundance and recruitment, and algal abundance, percent cover, and life history characteristics. These results will be presented in a final report in June 1996 In addition, new sets of erosion control fabrics will have been placed in the high intertidal as a means of reducing desiccation and of promoting *Fucus* germling survival. These data will be analyzed and reported in the final report.

B. Methods

Statistical analyses will remain the same as for previous years. The basic experimental design is an After Control-Impact Pair design in which an oiled site is statistically compared to a matched control or reference site that was unoiled. We will use fixed effects analysis between matched pairs (one-way ANOVA or t-tests) and Fisher's meta analysis tests for combining p-values within a habitat. By definition, "recovery" of a habitat or tidal height will be when the abundance or percent cover for oiled sites is the same as for control sites. Our operational definition for recovery for a particular taxon is when a taxon shows no significant difference between oiled and reference sites at $p < 0.05$ by Fisher's test.

C. Contracts and Other Agency Assistance

Principal investigators from the University of Alaska School of Fisheries and Ocean Sciences will cooperate to provide expertise on algal and invertebrate taxonomy and ecology.

The FY 95 field season will be implemented by the ADF&G. The University possesses the historical records of the Herring Bay sites and all of the raw and processed data from 1990 through 1994, and will be adding to the database through the 1995 field season. The University is in the best position to assure the consistency of the data to allow for comparisons to the previously collected data. The ADF&G is also currently involved in the monitoring and restoration of the nearshore through existing contracts with the University.

A contract will be issued to Coastal Resource Associates, Inc. (CRA) to assist in the analysis and report writing of *Fucus* monitoring and restoration data which will be collected with Dr. Stekoll in 1995.

D. Location

This study in FY 96 will take place in Fairbanks at the School of Fisheries and Ocean Sciences and at the Juneau Center School of Fisheries and Ocean Sciences in Juneau. The data which will be analyzed will have been collected in FY 95 from the intertidal zone in Herring Bay on Knight Island in Prince William Sound.

SCHEDULE

A. Measurable Project Tasks for FY96

Laboratory sample analysis, data analysis and graphics presentation will occur from October 95 to March 96. A draft final report will be submitted in June 1996. The final report will be submitted approximately four months after peer review.

B. Project Milestones and Endpoints

Objectives are to be met June 1996.

C. Project Reports

A draft final report will be submitted in June 1996. The final report will be submitted approximately four months after peer review.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This study will be conducted by a team of scientists with first hand experience in the monitoring of the effects of oil on intertidal communities. These investigators have worked together over the past five years to monitor the recovery of the intertidal community following the *T/V Exxon Valdez* oil spill. Principal investigators from the University of Alaska Fairbanks and University of Alaska Southeast will be coordinating efforts to study recovery of key algae and invertebrate species in the upper intertidal elevations.

ENVIRONMENTAL COMPLIANCE

This funding will support laboratory work and report writing and no permits or special requirements are anticipated.