Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators

Project Number:	01423
Restoration Category:	Research and Monitoring
Proposers:	Jim Bodkin, Dan Esler, Tom Dean, Brenda Ballachey
Lead Trustee Agency:	DOI--USGS
Cooperating Agencies:	
Alaska SeaLife Center:	Yes
Project Duration:	3rd year, 5-year project
Cost FY 01:	$362,100
Cost FY 02:	$363,700
Cost FY 03:	$250,000
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sea Otter, Harlequin Duck

ABSTRACT

Sea otters and harlequin ducks have not fully recovered from the EVOS, based on population-level demographic differences between oiled and unoiled areas. Further, in oiled areas, both species show elevated cytochrome P4501A (CYP1A) through 1998, almost certainly reflecting continued exposure to oil. We propose to explore links between oil exposure and the lack of population recovery, with the intent of understanding constraints to full recovery of these species and the nearshore environment generally. We also will monitor the progress of recovery of the species and the system. Proposed work consists of field components for both species, and a captive component for harlequin ducks. For sea otters, field studies include aerial surveys of distribution and abundance*, estimation of age-specific survival rates, and monitoring of CYP1A expression. For harlequin ducks, field studies will examine the relationship between survival and CYP1A and, further, will serve to monitor these key parameters. Captive experiments on harlequin ducks will examine the relationships between oil exposure and CYP1A induction, and the metabolic and behavioral consequences of exposure to oil.

* Sea otter aerial surveys be suspended in 2001, based on fiscal considerations and the need to re-sample sea otter survival and the bioindicator cytochrome P450 1a in that year. Aerial sea otter surveys will be continued in 2002 and because they provide the foundation for the other sea otter components, will remain identified, but highlighted, in this revised 2001 DPD.

INTRODUCTION

The nearshore environment of Prince William Sound (PWS) received about 40% of the oil spilled after the ***Exxon Valdez*** ran aground (Galt et al. 1991). Concerns about nearshore recovery and restoration resulted in a suite of studies sponsored by the ***Exxon Valdez*** Oil Spill Trustee Council, including the Nearshore Vertebrate Predator project (NVP). Principal findings of NVP include an apparent lack of population recovery for sea otters (***Enhydra lutris***) and harlequin ducks (***Histrionicus histrionicus***), both invertebrate feeders in the nearshore ecosystem (Bodkin et al. 1999; Esler et al. 1999). Over a three year period, harlequin ducks residing in oiled areas had poorer survival than those in unoiled areas (Esler et al. 2000a). Sea otters also experienced poor post-spill survival through 1998, based on modeling of ages-at-death (Monson et al. 2000). Further indication of increased mortality (or higher rates of emigration) of sea otters in oiled areas compared to their counterparts in unoiled areas is provided by inferences based on capture data (Bodkin et al. 1999). Additionally, both species show evidence of continuing exposure to hydrocarbons, based on higher levels of the biomarker cytochrome P4501A (CYP1A), in oiled areas than unoiled (Ballachey et al. 1999). Elevations in CYP1A are not explained by background or natural hydrocarbon sources, as these were found to be negligible in intertidal areas of PWS (Short and Babcock 1996), nor by area differences in PCB contamination (Trust et al. 2000; USFWS unpub. data), leaving continued exposure to residual ***Exxon Valdez*** oil as the most plausible explanation. Residual oil is still stranded in intertidal areas of PWS (Babcock et al. 1996; Hayes and Michel 1999).

Conceptual links have been drawn describing mechanisms by which oil exposure could have population-level demographic impacts on sea otters and harlequin ducks. However, these links, and thus the processes that may limit full recovery, remain speculative. Therefore, we propose to build on the base of knowledge gained through previous research to (1) explore the relationships between oil exposure, individual health, and demographic attributes that could have population level effects, and (2) monitor the parameters identified in previous work that are effective and statistically powerful in describing population status and lend insight into the process of recovery of sea otters and harlequin ducks, and the nearshore environment generally.

In addition to work previously proposed and approved as part of Project 00423, we are proposing a new component: CYP1A biomarker monitoring of sea otters. We are also requesting salary for the sea urchin PI for closeout of the sea urchin component conducted as part of 99423 & 00423. The costs for all components are identified in a table under "Explanation of changes in continued projects".

Sea Otters

The NVP study provided several lines of evidence indicating that sea otters in the most heavily oiled portions of western Prince William Sound (WPWS), at northern Knight and Naked islands, have not recovered from oil-related injury (Bodkin et al. 1999; Dean et al. 2000; Monson et al. 2000). The sea otter population at northern Knight has not increased between 1993-99 (the period for which we have aerial survey data), with numbers remaining at about half the estimated pre-spill abundance. Sea otters in oiled areas show reduced survival, relative to prespill rates (Bodkin et al. 1999; Monson et al. 2000). Levels of CYP1A are higher in sea otters from Knight Island than from unoiled reference areas, suggesting continued exposure to residual oil may be affecting recovery of the species. Additionally, increased proportions of larger-sized individuals of several sea otter prey species were identified at northern Knight, consistent with reduced predation and lack of recovery of the sea otter population in that area (Dean et al. 2000).

The sea otter component of this proposal builds on previous EVOS research (93045, 95025-99025) to develop a statistically sensitive and cost-effective program that will continue to track the WPWS sea otter population and nearshore ecosystem recovery, and investigate the effects of chronic oil exposure on sea otters. We will address the following questions: (1) are sea otters increasing in abundance in the most heavily oiled areas, and in western PWS overall (aerial surveys suspended in 2001)? (2) has survival of sea otters returned to pre-spill rates? and (3) has exposure of sea otters to residual oil declined over time?

Question 1 will be answered by continued aerial surveys of sea otter abundance at appropriate intervals to monitor the population and test predictions of a previously developed sea otter population model (Restoration study 99043; Udevitz et al. 1996). Surveys were done in 1999 and 2000, and will be conducted again in 2002 and 2003. ***This element is a continuation of work proposed and approved in Project 99423, and initiated in Project 99423.***

Question 2, regarding survival rates of sea otters, involves a modeling effort that utilizes ages-at-death of sea otters recovered as carcasses on beaches (Monson et al. 2000). This element was not initially included as part of Project 99423, but due to the compelling evidence of long-term injury provided by the modeling results in late 1999, the carcass surveys were added for FY2000 (supplementary funding provided in February 2000). We propose that carcass surveys be conducted again in 2001.

Question 3 is a new element for FY2001, which will be addressed by monitoring CYP1A expression in sea otters in WPWS for comparison with 1996-98 data. Depending on results of surveys and year 2001 measures of CYP1A, it may not be necessary to continue CYP1A measures beyond 2001.

Harlequin Ducks

The most concerning result from NVP harlequin duck studies was the detection of significantly lower survival probabilities of adult females in oiled areas of PWS than in unoiled areas (Esler et al. 2000a). Analyses revealed that history of oil contamination was a more likely explanation for the survival difference than intrinsic differences between oiled and unoiled study areas. Further, projections of population trends using models incorporating these survival probabilities predicted declining populations on oiled areas and increasing populations on unoiled areas. This pattern was observed during Alaska Department of Fish and Game surveys (EVOSTC Project /427), suggesting that differences in survival were a likely mechanism for observed differences in population trends. Also, harlequin duck densities were lower on oiled Knight Island than on unoiled Montague Island, after accounting for intrinsic habitat differences; this is the pattern that would be predicted given high site fidelity and poorer survival on oiled areas. Finally, higher levels of CYP1A induction were detected on oiled areas.

Results from these recent studies lead to speculation that continued exposure to oil could result in poorer survival of harlequin ducks, which in turn would result in differences in population trends and densities. There are reasonable explanations for how oil may be related to survival (see Statement of Problem below). Unfortunately, however, these links are drawn from a wide array of sources, with limited inference to wild harlequin ducks in PWS. Thus, we propose studies that will explore the relationship between oil exposure and survival using both field and captive bird approaches. These will serve to examine mechanisms or processes that may continue to limit harlequin duck population recovery. These studies also will monitor the most critical elements revealed in previous studies to gauge the progress of recovery.

The specific questions that will be asked by the harlequin duck components of this study are: (1) what is the relationship between levels of oil exposure and CYP1A induction, and what levels of oil exposure result in CYP1A values similar to those measured in PWS? (2) are there metabolic or behavioral consequences of oil exposure that could be a mechanism by which harlequin duck survival is compromised? (3) is oil exposure (as indicated by CYP1A induction) related to survival of harlequin ducks in the wild? and (4) is contaminant exposure declining over time and, similarly, are survival rates on the oiled area improving through time? Questions 1 and 2 will be addressed using captive birds at the Alaska SeaLife Center during winters 2000-01 and 2001-02. Questions 3 and 4 will be addressed by biosampling and radio telemetry work during winters 2000-01, 2001-02, and 2002-03. ***These studies are a continuation of work proposed and approved in Project 00423.*** This work will examine both the process of recovery (through understanding of the mechanisms constraining population demography) and will monitor the progress of recovery by sampling survival and CYP1A induction of wild birds starting 3 years subsequent to the last work done as part of NVP (winter 1997-98). Proposed survey work by the Alaska Department of Fish and Game would aid interpretation of field studies and would also monitor population recovery.

NEED FOR THE PROJECT

A. Statement of Problem

Sea otters and harlequin ducks occupy an invertebrate-consuming trophic level in the nearshore and are conspicuous components of the nearshore ecosystem. In 1995, the NVP Project was initiated to examine the status of recovery of nearshore vertebrates (including sea otters, harlequin ducks, river otters and pigeon guillemots), and to evaluate possible causes for the apparent lack of recovery. Results of the NVP project clearly suggest that complete recovery has not occurred for sea otters and harlequin ducks, and the lack of recovery may be related to continued exposure to oil. This proposed work follows up on the critical elements revealed by the NVP studies, in particular the relation between population status and oil contamination, and evaluation of population status.

In addition to observations made directly on predator species, as part of the NVP project, we have observed an apparent response among several invertebrates to reduced sea otter densities. This finding represents a shift in the ecological processes structuring the nearshore community and provides a unique opportunity to test predictions related to sea otter recovery and their prey. We also have an opportunity to test the application of this novel approach as a tool for monitoring predators through prey that may have broader ecological applications.

Sea Otters

The sea otter population in WPWS was injured as a result of the spill. Estimates of sea otter mortality due to the spill range from 750 to 2,650 individuals (Garshelis 1997, Garrott et al. 1993). A population model (Udevitz et al. 1996) predicted recovery of the WPWS sea otter population in 10 to 23 years, projecting maximum annual growth rates from 0.10-0.14. Surveys to date (1993-1998) have shown a significant increasing trend in the WPWS sea otter population, averaging about 4% per year since 1993 (power > 0.80 to detect a 1% annual change in 5 annual WPWS surveys). In contrast to the western Sound overall, at northern Knight Island sea otter numbers remain below pre-spill estimates and do not show a significant increasing trend (Figure 1; Bodkin et al. 1999; Dean et al. 2000; USGS unpub. data), although our power to detect change is lower for these surveys.

Aerial survey data of sea otter abundance have provided the foundation for assessment of recovery status in WPWS. However, pre-spill data of abundance are few, and there are known biases in pre-spill estimates that preclude using pre- vs. post-spill comparisons in making a definitive quantitative assessment of the extent of recovery. Furthermore, recovery status could not be based solely on post-spill comparisons of oiled and unoiled areas because there are recognized differences in habitat between these areas, and it is uncertain whether sea otters in oiled areas could ever achieve population densities observed in unoiled parts of the Sound. As a result, in the NVP study, we examined prey populations as an ancillary means of assessing recovery.

This approach was based on the knowledge that sea otters have a profound and predictable effect on the structure of prey populations (reviewed in Riedman and Estes 1990). Generally, as sea otters reoccupy an area, they first consume the largest members of the most energetically profitable prey, eventually switching to smaller sizes and different species as preferred species and the larger size classes become rare (Estes and Palmisano 1974, Duggins 1980, Estes and Duggins 1995). Based on these findings, we hypothesized that a reduction in otter abundance would be accompanied by an increase in the abundance and average size of prey. We concluded that the status of recovery of impacted populations of sea otters might therefore be assessed by examining the abundance and size-distributions of prey within impacted areas, and by comparing these with estimates from an unaffected area where otters and their prey were considered to be in equilibrium. Full recovery would be indicated by similar abundances and size distributions of prey in oiled and unoiled areas.

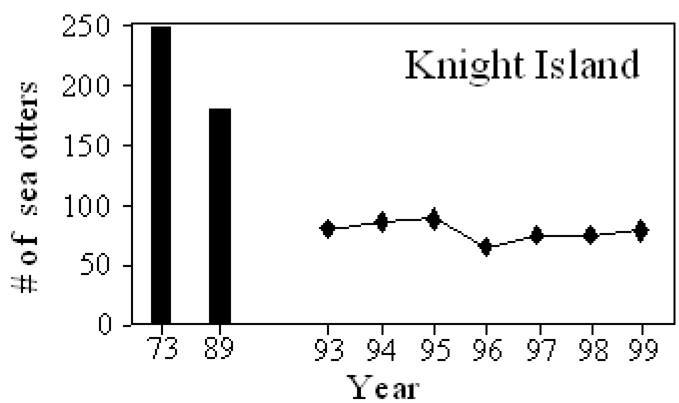

Figure 1. Estimated sea otter abundance at northern Knight Island.

NVP comparisons of most invertebrate prey populations between Knight Island (oiled) and Montague Island (unoiled) identify differences in prey population structure consistent with lack of recovery of the sea otter population at the oiled site (Dean et al. 1999). At the sites where sea otter populations were greatly reduced, we found significantly greater proportions of large individuals among most species of clams, urchins and mussels. Prey assessment (sea urchins only) was continued as part of 99423 and 00423, to further test this approach to estimating the status of a predator population. We predicted that differences in prey sizes between areas should diminish when sea otter populations near complete recovery. However, sampling intensity in the past two seasons has been less than during the NVP project, and variation in size of sea urchins has been high. Thus, at this time, we do not propose further monitoring of the size and abundance of sea urchins in oiled and unoiled areas of WPWS to assess the recovery status of sea otters, and are requesting only funds to close out this component in FY01.

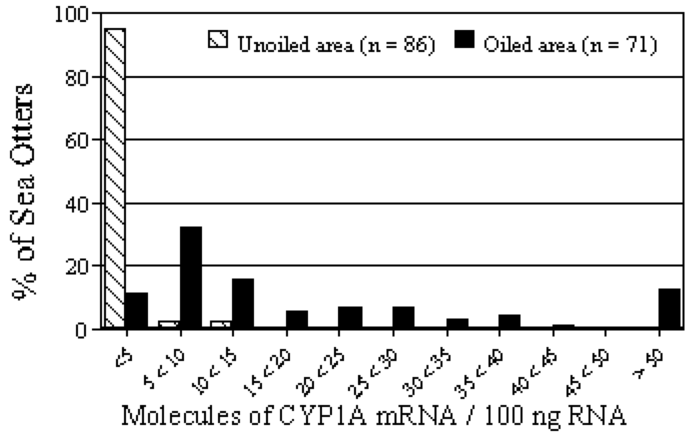

Figure 2. Measurement of cytochrome P4501A induction (RT-PCR technique) in sea otters in western Prince William Sound, 1996-98.

Sea otter carcasses have been recovered from beaches in WPWS since 1976, thus providing one of the few long-term baseline data sets for evaluating post-spill injury. Carcass surveys initially were not proposed as part of Project 99423. However, in 1999 we applied recently developed modeling techniques (Doak and Morris 1999) to estimation of sea otter survival rates, utilizing the distribution of otter ages-at-death as the basis for the model. The results provide compelling evidence of long-term injury from the EVOS (Monson et al. 2000). Briefly, the model involves a comparison of observed vs. predicted ages-at-death of sea otters prespill and postspill, using data from carcasses collected during 1976-98. Postspill survival of sea otters in the western Sound was poor relative to prespill rates, and by 1998, survival rates had not yet returned to prespill values. However, survival rates of younger age otters were increasing, suggesting that conditions were normalizing. These results are consistent with other observations of sea otters in western PWS, which suggest that the population in the most heavily oiled areas has not yet recovered (Figure 1). Carcass collections and modeling efforts based on age-at-death data may provide one of the most efficient tools for monitoring recovery of sea otters. Thus, we propose that carcass surveys (and subsequent modeling to estimate survival rates) be continued in 2001, as an additional tool for monitoring sea otter recovery in PWS.

The NVP study identified elevated expression of CYP1A in 6 species that inhabit the nearshore areas of WPWS, indicating continued exposure to residual EVOS oil (Ballachey et al. 1999). Sea otters were sampled in 1996-98, and in all years, animals from Knight and Naked islands (oiled area) had elevated CYP1A, compared to those from Montague Island (unoiled area; Figure 2). Further, levels at Montague were similar to those measured in otters from a relatively clean area in southeast Alaska with no known exposure to oil or other contaminants (USGS unpub. data). In 1998, the mean value of CYP1A in the oiled study area was lower than means for 1996 or 1997, suggesting exposure to residual oil is diminishing over time. We propose to resample the wild sea otter population for CYP1A in summer 2001, to determine if hydrocarbon exposure continues, and if so, if it has declined relative to levels measured in 1996-98. Sea otters in the most heavily oiled areas of WPWS will be targeted for sampling, with particular effort to capture those residing in the vicinities of known persistent oiled shoreline and bivalve populations (Hayes and Michel 1999, Fukuyama et al. in press) and oiled mussel beds (Harris et al. 2000), potentially enabling us to make a link between biomarker levels in sea otters and petroleum contaminants in mussels and sediments of their nearby habitat. Sea otters from Montague Island will also be captured to provide a non-exposed reference sample.

In summary, we propose continued monitoring of sea otter distribution and abundance, survival rates and oil exposure (CYP1A) in WPWS. These studies will be valuable in documenting actual recovery time for the nearshore system including sea otters, and providing long-term population trend data which may be used in assessing initial damage and subsequent recovery of sea otter populations in the event of future oil spills.

Harlequin Ducks

Harlequin ducks were, and remain, particularly vulnerable to deleterious effects of the oil spill. Much of the oil from the ***Exxon Valdez*** was deposited in the nearshore intertidal and shallow subtidal zones (Galt et al. 1991), the coastal habitats where harlequin ducks occur. Also, Goudie and Ankney (1986) suggested that harlequins were near the lower limit of body size for sea ducks occurring in environments similar to Prince William Sound in winter. Because harlequin ducks exist close to an energetic threshold, any perturbation (e.g., an oil spill) that either affects health or condition directly (via toxic effects or increased metabolic costs) or indirectly (via food abundance) could have significant consequences for the population.

Also, among ducks, sea duck life histories are particularly K-selected (Eadie et al. 1988). Harlequin ducks typically defer reproduction for 3 years, have relatively low annual investment in reproduction, and are long-lived (Goudie et al. 1994). Species with these characteristics have relatively low potential rates of population change and, thus, following a perturbation such as an oil spill, require many years in the absence of continued adverse effects to recover to previous population levels. Further, population dynamics of animals with this life history strategy are particularly sensitive to variation in adult survival (Goudie et al. 1994, Schmutz et al. 1997).

Sea ducks have a general pattern of high philopatry throughout their annual cycle (e.g., Limpert 1980, Savard and Eadie 1989) and harlequin ducks follow this pattern, having high fidelity to molting and wintering sites (Robertson 1997; Esler, unpubl. data). High site fidelity could result in vulnerability to population effects because: (1) if residual oil spill damages exist, birds from oiled areas are vulnerable to spill effects as they return to those areas annually (i.e., these birds are affected disproportionately and are subject to cumulative effects), and (2) if dispersal and movements among areas are limited, recovery of groups of birds in oiled areas can occur only through demographic processes specific to that group (i.e., numbers are not enhanced through immigration from other areas). High site fidelity is an adaptive behavioral strategy in natural situations and predictable environments (Robertson 1997), but does not accommodate movement to undisturbed sites in the face of human-caused perturbations.

Evidence from recent studies (NVP and /427) suggests that, as might be predicted from their vulnerability, harlequin duck populations have not fully recovered and, in fact, continue to suffer deleterious effects from the oil spill. Over the course of 3 winters, survival probabilities differed between oiled and unoiled areas (Figure 3). Survival probabilities were high, and similar between areas, in fall. However, survival diverged between areas during mid-winter, presumably the period during which conditions are most difficult for harlequin ducks. Also, differences in CYP1A induction were detected between populations from oiled and unoiled areas (Figure 4; Trust et al. 2000), although this was measured on different birds than those for which survival data were collected. Further, body mass during winter showed a slight, negative relationship with CYP1A level.

One can speculate on mechanisms by which continued exposure to oil could be related to differences in survival probabilities. Most lab studies have shown that mallards are tolerant of internal ingestion of oil, with toxic effects not evident until very high doses. These studies have been used to suggest that harlequin ducks should, similarly, be unaffected by residual Exxon Valdez oil (Stubblefield et al. 1995, Boehm et al. 1996). However, other studies have found that, with addition of other stressors such as cold temperatures, oiled ducks in the lab suffered considerably higher mortality than unoiled (Holmes et al. 1978, 1979). This seems to be a much more appropriate analog for wild harlequin ducks. Particularly given their vulnerability to spill effects and hypothesized existence near an energetic threshold, harlequin ducks may not be able to handle additive effects of the oil spill, even if relatively small.

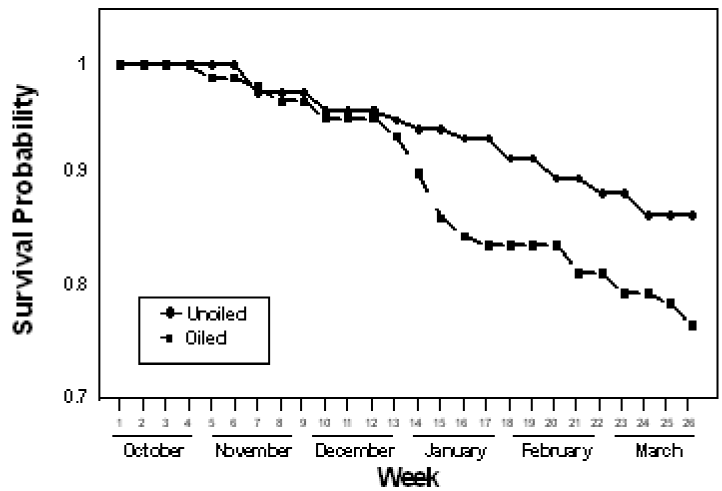

Figure 3. Survival probabilities of harlequin ducks.

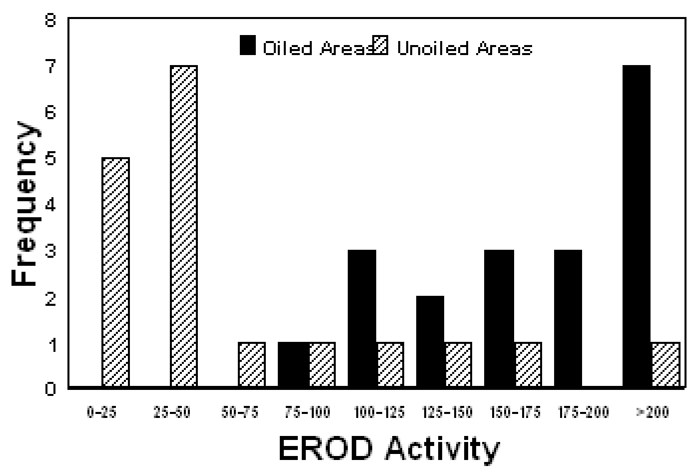

Figure 4. Comparison of CYP1A induction (hepatic EROD activity) in harlequin ducks from Prince William Sound.

To fully understand the process of harlequin duck population recovery from the oil spill, it is important to address these speculated links between oil exposure and survival probabilities, and subsequently population trends. The research proposed here is designed to explore these potential mechanisms constraining population recovery through field studies of winter survival and CYP1A induction and captive studies of metabolic, behavioral and CYP1A responses to controlled oil exposure. Further, because of their susceptibility to spill effects and high site fidelity, harlequin ducks are an ideal species for monitoring recovery of the nearshore environment.

B. Rationale/Link to Restoration

Sea otter and harlequin duck restoration requires assessments of population recovery status and definition of impediments to recovery. For harlequins and sea otters, the proposed work incorporates monitoring activities which, given the "baseline" data collected in NVP and other post-spill studies, will allow us to gauge recovery status. Additionally, the research components proposed herein represent a comprehensive approach to understanding the factors that affect population dynamics and definition of critical bottlenecks to recovery. Without an understanding of the underlying processes that dictate population change, we can not prescribe specific activities to enhance recovery. The project directly addresses the restoration objectives both by examining the processes affecting recovery and by monitoring the progress of recovery, including survival rates and contaminant exposure.

Sea Otters

Recovery of sea otters will be complete when population size returns to estimated pre-spill abundance, and there is no further evidence of continuing exposure to residual oil. Sea otter restoration requires an understanding of population status and the processes affecting changes in population status. Continued monitoring of sea otter distribution, abundance, survival rates and prey populations in WPWS will provide insight into recovery and improve future recovery models, and potentially allow us to document the actual recovery time for the nearshore system, including sea otters. A further benefit of these project components is provision of long-term population trend data and monitoring tools which may be used in assessing initial damage and subsequent recovery of sea otter populations in the event of future oil spills.

Harlequin Ducks

Harlequin duck restoration will be complete when densities have recovered to prespill levels and birds no longer show evidence of oil contamination. Poor survival in oiled areas is the most plausible cause for lack of recovery to prespill densities; restoration requires an understanding of the factors that affect survival rates, in particular the effects of oil exposure. The restoration objectives for harlequin ducks are addressed both by examining the processes affecting recovery and by monitoring the progress of recovery, in particular contaminant exposure.

C. Location

Studies will be conducted in PWS. Specific study sites for the sea otter components will be northern Knight Island and Port Chalmers/Stockdale at Montague Island, as used in the NVP project. Harlequin duck study sites also will be those used in previous NVP work: unoiled Montague Island and oiled Green Island, Crafton Island, Main Bay and Foul Bay. Captive studies will be done at the Alaska SeaLife Center in Seward. Communities affected by the project include Chenega, Whittier, Cordova and Seward.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The project will continue to inform and coordinate our community involvement activities, including the collection of indigenous knowledge with Dr. Henry Huntington, TEK specialist Chugach Regional Resources Commission and Hugh Short, Community Coordinator, EVOS Restoration Office. We will continue to solicit advice from the above parties and gather information on TEK through local community facilitators and residents.
Efforts have and will continue to be made throughout the restoration process to participate in and provide public involvement in the design and implementation of this project. Information gathered from this project will be shared with local communities. Project staff has and will continue to present information to local communities or prepare articles or photographs for Trustee Council publications. Boat and air charter contracts, and other services will be contracted from local sources when possible.

PROJECT DESIGN

A. Objectives

Sea Otters

Field Studies

1. Estimate of sea otter abundance and population trends over time in WPWS overall, and in oiled and unoiled study areas within WPWS (suspended in 2001).

2. Monitor progress of sea otter population recovery via tracking of survival rates in oiled areas.

3. Monitor CYP1A induction in sea otters in oiled and unoiled areas, as an additional measure of population recovery.

Harlequin Ducks

Field Studies

1. Estimate winter survival rates of harlequin ducks in relation to area (history of oil contamination) and indices of oil exposure (CYP1A induction).

2. Monitor progress of harlequin duck population recovery via tracking of survival rates and CYP1A induction in oiled and unoiled areas.

Captive Studies

1. Measure the CYP1A response in oil-dosed, captive harlequin ducks.

2. Quantify the metabolic and behavioral consequences of oil exposure.

B. Methods

The proposed research employs field studies on sea otters, and both field studies and experimental work with harlequin ducks. This combination of approaches addresses the need for controlled work to look explicitly at the effects of oil exposure on hypothesized mechanisms of mortality and field work to document the relevance of those mechanisms under wild conditions. With captive studies on harlequin ducks, we propose to quantify metabolic and behavioral responses to known regimes of oil exposure as well as indicate the level of oil exposure that corresponds to CYP1A induction detected in the field. For both species, field studies are necessary to understand the relevance of these relationships to animals in the wild, and to monitor population and system recovery.

Sea Otters

Field Studies

The proposed sea otter work employs aerial surveys to track population abundance and growth, and sampling of intertidal green sea urchins to assess sea otter-prey interactions. These approaches will provide information on recovery status of the population, assessed by growth rates and prey structuring. Additional components proposed for 2001 are collection of carcasses for determination of ages at death, to be used in estimation of survival rates, and monitoring of CYP1A levels in sea otters as an indication of chronic oil exposure.

Sea otter population monitoring--We will continue to use previously developed aerial survey techniques which employ counts along systematic transects, and intensive search units (ISU's) to estimate a correction factor for each survey (Bodkin and Udevitz, 1999). We will conduct a single survey of the entire PWS every two years beginning in 1999, and in alternate years, conduct a survey of WPWS. From the combination, we will obtain an estimated population size for WPWS annually (except in 2001). We will continue annual replicate surveys (5 or more replications per survey) of the smaller NVP study sites, initiated in 1999 (except in 2001).

Carcass surveys--Age specific survival estimates will be generated based on age distributions of the dying portion of the population, will be evaluated through recovery of beach-cast sea otter carcasses in western PWS. Beaches will be surveyed once during late April or early May after snow melt but prior to summer revegetation, which may hide carcasses washed high on the beach by winter storms. Data recorded for each carcass include: (1) relative location of carcass on the beach, 2) relative condition and completeness of carcass, (3) position of remains relative to previous year's vegetation, (4) relative age (adult, subadult, pup), (5) sex, and (6) specimens collected (e.g., entire carcass, skull, baculum, none). Skulls (when present) will be taken from all carcasses and a tooth extracted for aging (Bodkin et al. 1997). Any fresh carcasses collected will be necropsied as soon as possible and tissue samples collected for potential toxicology and histopathology studies.

Cytochrome P450 1A--In summer 2001, we will capture 30 sea otters in oiled and unoiled areas (15 per area). We will capture in the same general locations (Knight and Montague islands) that were sampled in the NVP project so that data can be directly compared to previous (1996-98) results. In addition, we will attempt to capture otters in the vicinity of shorelines known to be contaminated with oil (Hays and Michel 1999; Fukuyama et al. in press) and mussel beds being monitored as part of Restoration Project 00090 (Harris et al. 2000). Capture and handling methods will be similar to those employed previously (Bodkin et al. 1999). Sea otters will be sedated, body measurements taken, a tooth collected for age determination, and a blood sample taken by jugular venipuncture. Each otter will be tagged with two color-coded, numbered flipper tags. Following reversal, sea otters will be released in the same vicinity as captured.

In the NVP study, the RT-PCR assay (quantitative reverse transcriptase PCR assay; Vanden Heuvel et al. 1993, 1994) was adapted to measure CYP1A levels in sea otters. This assay quantifies the messenger RNA (m-RNA) that codes for the CYP1A protein. Initially, the RT-PCR assays required the isolation, cloning and sequencing of the PCR product, and the development of sea otter specific primers for CYP1A (Snyder et al. 1999); that work is now complete. Results of the assay are reported as the molecules of mRNA per 100 ng of RNA. We will continue to use peripheral blood mononuclear cells collected from live otters for the assay. The peripheral blood lymphocytes will be isolated by a ficoll gradient technique, cryopreserved in liquid nitrogen and shipped to Dr. P. Snyder at Purdue University for analyses. In addition, duplicate slides of whole blood will be made for hematology, and blood from each otter will be processed to obtain serum, which will be frozen and later submitted for serology analysis.

Harlequin Ducks

Field Studies

The key data for field studies are paired CYP1A and survival data, which will allow for explicit tests of the hypothesis that mortality and oil exposure are related in wild harlequin ducks. We intend to collect survival and exposure data from 50 birds in each of 3 years by capturing them during early winter, conducting surgeries to both implant transmitters and biopsy livers, and monitoring subsequent winter survival. These types of data have been successfully collected during NVP studies.

This research requires capture of flighted harlequin ducks during early winter, after they have been on wintering sites long enough to be potentially exposed to residual oil, yet before the mid-winter period when survival probabilities diverged during NVP studies (Figure 3). The mid-winter period is presumably the time of greatest stress and thus the period when oil spill effects would be most likely to be expressed as differences in survival probabilities. The interval between capture and the critical mid-winter period must allow for at least a 2-week censor period to ensure that survival data are not biased by effects of capture, handling, or surgery (Esler et al. 2000b; Mulcahy and Esler 1999). Thus, we propose capturing birds during a 3-week period in November to generate both survival data and exposure data from the same individuals.

We will use floating mist nets (Kaiser et al. 1995) to catch flying birds in oiled (Knight Island, Green Island, Crafton Island, Main Bay, Foul Bay) and unoiled (Montague Island) study areas. Use of the same study areas as the NVP project allows for direct comparisons of results. The floating mist net capture technique was used successfully during NVP studies. However, this technique does not allow handling of as many birds as molt drives, so age and sex cohorts used in survival estimation will not be as restricted as in NVP studies. We will radio birds of both genders and all age classes older than hatch-year. Age and sex parameters will be included in all analyses to account for any survival differences due to these effects. Captured birds will be banded with uniquely coded USFWS bands, aged by bursal probing (Mather and Esler 1999), and sexed by plumage characteristics.

To estimate survival probabilities of harlequin ducks, we will use implantable radio transmitters with external antennas (Korschgen et al. 1996). Implanted transmitters have been successfully used in waterfowl studies (e.g., Olsen et al. 1992, Haramis et al. 1993), and an increasing body of literature suggests that radio transmitters implanted into wild waterfowl are less disruptive than external methods of attachment, based on differences in survival or return rates (Ward and Flint 1995, Dzus and Clark 1996), behavior (Pietz et al. 1993), and reproductive rates (Pietz et al. 1993, Rotella et al. 1993, Ward and Flint 1995, Paquette et al. 1997), especially for diving ducks (Korschgen et al. 1984). NVP studies (Esler et al. 2000b) demonstrated that recapture probabilities of radio-marked harlequin ducks were not lower than unradioed individuals. Surgeries will be conducted by certified veterinarians experienced in avian implant surgeries, following procedures outlined in Alaska Biological Science Center, USGS Biological Resources Division standard protocol. Transmitters will weigh approximately 18g, which is $\leq$ 3% of the body mass of the smallest wintering female harlequin ducks captured during NVP studies. Transmitters will be equipped with mortality sensors; the pulse rate will change from 45 to 90 beats per minute when a mortality is indicated. Mortality status will be confirmed by either carcass recovery or detection of signals from upland habitats, which are not used by harlequin ducks during nonbreeding periods.

We will conduct radio telemetry flights at approximately weekly intervals from the capture and marking period through the end of March. Survival data entry and general description will follow procedures outlined in Pollock et al. (1989a, 1989b), as modified by Bunck et al. (1995). We will examine effects of area, season, and CYP 1A on survival by comparing AIC_c values (Burnham and Anderson 1998) among models with different combinations of these effects. The AIC_c indicates the most parsimonious model by balancing the goodness-of-fit of each model (from the maximum likelihood) with the number of parameters to be estimated. Under this approach, the model with the lowest AIC_c indicates the combination of parameters that are best supported by the data, which we will interpret as the factors related to variation in survival. Survival estimates and variances will be calculated by iterative solution of the likelihood using program MARK (White and Burnham 1999).

CYP1A induction will be measured by EROD activity. Small liver biopsies (approximately 0.1 g) will be surgically removed and immediately frozen in a liquid nitrogen shipper. EROD activity analyses will be conducted in a contracted lab following standard procedures (Trust et al. 2000). Plumage swabs (Duffy et al. 1999) will be used to assess presence of external oil.

For field studies, work in FY00 includes ordering radios (and designing a transmitter that avoids problems with extrusion [Mulcahy et al. 1999]), building winter traps, and other preparations (i.e., researching boat and air charter options, etc.). Field work will begin in early FY01 (November 2000).

Captive Studies

Captive bird studies will examine metabolic, behavioral, and biomarker responses to known oil-dosing regimes. This work is designed to experimentally test effects of oil exposure on parameters that are hypothesized to influence dynamics of wild harlequin duck populations; these effects are impossible to assess under field conditions.

Harlequin ducks to be used in captive studies will be captured during wing molt from unoiled parts of PWS. During molt, harlequin ducks congregate and are susceptible to capture by herding flocks of flightless birds into pens (Clarkson and Goudie 1994). Birds will be banded with USFWS bands and with individually coded plastic tarsus bands. Tarsus bands will be oriented to be read from bottom to top as the bird is standing. Sex will be identified based on plumage characteristics and age class determined by bursal probing (Mather and Esler 1999). Body mass of all birds at capture will be measured.

Following capture, birds will be flown to the Alaska SeaLife Center in Seward. We intend to use approximately 20 birds each year for 2 years (winters 2000-01 and 2001-02). Captured individuals will undergo quarantine and adjustment periods prior to any experimental manipulation or dosing. Captive birds will be housed in outdoor pens to expose them to natural climatic and photoperiod conditions. Dosing will be designed to simulate long-term, intermittent exposure, which is likely similar to exposure experienced by wild birds. Numbers of dosing levels, amounts of doses, and frequency of dosing will be determined as part of literature review efforts proposed for FY00. Dosing will continue through the critical mid-winter period and behavioral and metabolic measures will be taken throughout the winter. Because CYP1A sampling requires a liver biopsy, we will get only 1 measure of induction, taken in late winter. Following a 2-week post-surgery recovery period (without any dosing), captive birds will be released in the area of their original capture.

Behavior of captive birds will be quantified using time-activity observations throughout winter for all dosing levels. Behavioral categories will follow those used in studies of wild harlequin ducks (Goudie and Ankney 1986, Fischer 1998), e.g., feeding, resting, swimming, courtship, etc. Time-activity budgets will be contrasted among dosing groups.

Metabolic consequences of oil exposure will be quantified using two approaches: doubly-labeled water to estimate daily energy expenditure (DEE) and oxygen consumption to estimate basal metabolic rate (BMR). This approach will allow different views into the metabolic effects of exposure. DEE is a measure of existence costs over longer (1-3 day) time periods. DEE incorporates all of the metabolic costs during this time; elevated DEE in exposed birds would be consistent with a hypothesis of oil exposure increasing existence costs with potential survival implications. Similar DEE among treatments but different activity levels (see above) also would have implications for survival under natural conditions. BMR estimates metabolism without costs of thermoregulation, digestion, and activity; these data will assess whether background metabolic costs are higher in dosed than undosed birds. Body mass of all individuals also will be measured at all handling events; these data will be interpreted in light of metabolic and behavioral measurements.

DEE estimation using doubly-labeled water requires injection of water with both the oxygen and water isotopically-labeled. As the hydrogen is lost only through water and oxygen through both water loss and carbon dioxide production, the difference in turnover rates between marked hydrogen and oxygen can be used to estimate metabolism. BMR will be measured using a flow-through respirometer to measure oxygen consumption. A metabolic chamber for harlequin ducks will be built during FY00 preparations; an oxygen analyzer is on site at the Alaska SeaLife Center. BMR of all birds will be measured throughout the winter, including prior to any dosing to establish background rates.

CYP1A induction of all captive birds will be measured at the end of the experiment by EROD activity, described above. EROD activity will be compared among all treatments.

FY00 effort will include research to determine appropriate dosing regime, preparation of facilities at the SeaLife Center to house birds and conduct experiments, construction of an appropriate metabolic chamber for oxygen consumption measurements, field work to catch birds to establish the first winter's captive flock, and refinement of the experimental design and protocol. Experimental work will commence in early FY01 (fall 2000).

C. Cooperating Agencies, Contracts, and Other Agency Assistance

USGS-BRD personnel will be responsible for directing and conducting sea otter and harlequin duck studies.

Contract with Coastal Resources (Dr. Tom Dean) for close out of the sea otter invertebrate prey monitoring component.

Contract with Dr. Paul Snyder at Purdue University for assays of RT-PCR CYP1A, sea otter CYP1A monitoring (WPWS population and captive sea otters at ASLC).

SCHEDULE

A. Measurable Project Tasks for FY01

Sea Otters

December-March:	Coordinate and plan aerial surveys, carcass collections, sea otter capture, community involvement, prepare equipment. Obtain/update marine mammal permits.
April-May:	Collection of beach-cast carcasses for survival estimates.
July:	Aerial surveys of sea otters in PWS (suspended in 2001). Capture of sea otters in WPWS for biosampling, to monitor CYP1A.

Harlequin Ducks

Oct-March:	Conduct studies of captive flock at the Alaska SeaLife Center, with birds captured during late FY00.
November:	Capture harlequin ducks for field studies of survival and CYP1A induction.
Nov-March:	Monitor radioed birds for survival study.
March:	Surgically biopsy livers of captive birds for EROD activity; after a recovery period, birds will be released at the original capture site.

April - August:	Prepare for field studies (e.g., order radios, contact boat charter operators, build winter trap, contact biosample contractors, etc.). Prepare for year 2 captive bird studies (coordinate with Alaska SeaLife Center personnel, determine year 2 dosing regime, arrange boat and air charters, etc.).
August - Sept.:	Capture birds during wing molt for creation of year 2 captive flock and initiate adjustment period.

B. Project Milestones and Endpoints

This is a projected five-year research and monitoring program (initiated FY99, with completion of all objectives by FY03; see below) designed to assess the recovery of two injured species. Project objectives will be assessed annually. At the end of each year results will be compared with the restoration goals to assess whether recovery has occurred. The reporting schedule is described below, and is consistent with EVOS Trustee Council guidelines.

Sea Otters

FY01-03: Field studies (carcass surveys, CYP1A monitoring) are scheduled to occur from April through July, 2001. Aerial surveys will be repeated in the summers of 2002 and 2003. Sea urchin monitoring will be closed out by September 2001. Carcass surveys and CYP1A monitoring will be repeated in April and July 2002, if warranted based on previous years of data.

Harlequin Ducks

FY01-03: Field studies are scheduled to occur from November through March, winters 2000-01, 2001-02, and 2002-03. Captive bird experimental work is scheduled for winters 2000-01 and 2001-02.

C. Completion Date

All project objectives will be met by FY03.

PUBLICATIONS AND REPORTS

Annual reports will be presented to the Chief Scientist by April 15. An annual report of FY01 activities will be submitted to the Restoration Office on or before 15 April 2002. A final report will be prepared at the end of the proposed work unless continued monitoring is warranted or when recovery objectives are met. Special reports (publications) will be prepared during the course of the study if warranted. Publications will be prepared for peer-review journals when sufficient data have been collected.

PROFESSIONAL CONFERENCES

D. Esler attendance at 2nd North American Duck Conference, 11-15 October, Saskatoon, Saskatchewan, to present a paper entitled, "Harlequin Ducks and the ***Exxon Valdez*** Oil Spill: Collision of a Sensitive Life History and a Major Anthropogenic Perturbation." B. Ballachey attendance at Environmental Toxicology and Chemistry meeting, session: "Effects and Trends of Contaminants in Marine Mammals", 12-16 November 200, Nashville, TN, to present on comparison of techniques for measuring cytochrome P4501A in sea otters exposed to petroleum hydrocarbons.

NORMAL AGENCY MANAGEMENT

The work proposed here is not part of normal agency management and is related specifically to research addressing oil spill restoration concerns. No similar work has been conducted, is currently being conducted, or is planned using agency funds.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

As described in the Introduction, this research relies on incorporation of data from other Trustee sponsored research, including projects /025 and /427. Equipment and commodities purchased under /025 will be used to conduct the proposed research and data collection and analysis will follow previously established protocols and standards.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

In 1998, the EVOS Trustee Council first approved funding for Restoration Project 99423, "Patterns and Processes of Population Change in Sea Otters", an extension of the NVP project. The objectives of the project included sea otter aerial surveys of PWS, replicate surveys of sea otters at Knight and Montague Islands and sampling of sea urchin populations. In 1999, the Trustee Council approved the addition of harlequin duck studies to 00423 with the revised project title "Patterns and Processes of Change in Selected Nearshore Vertebrates". Those studies included relating harlequin survival to oil exposure and captive studies to assess responses to controlled oil exposure. In February 2000, the Trustee Council approved an amendment to 00423, to fund carcass recovery surveys in WPWS, to collect data on sea otter ages at death for estimation of survival rates.

Differences in this 01423 proposal from projections in the 00423 proposal include increases in salary: three additional months for Dan Esler, PI on the harlequin ducks studies (as per correspondence of July 1999, D. Bohn and S. Schubert), to more accurately reflect the time needed to supervise and conduct this research, and one month for Tom Dean, PI on the sea urchin studies, to support data analyses and interpretation, and preparation of the final report on the prey assessment component (we are not proposing that prey monitoring continue beyond FY00).
The 01423 proposal also includes a new component, monitoring of the CYP1A biomarker in sea otters in western PWS. In addition, the carcass recovery surveys, approved as an amendment to 00423, are proposed again for 2001.

In July 2000, the project 01423 budget and DPD were revised to reflect suspension of the aerial surveys for sea otters in July 2001. Because salary costs were included in aerial surveys and also supported urchin work that is discontinued in 2001, salary costs of 28.8 K were redirected from aerial surveys to sea otter biomarker and survival sampling. Because aerial surveys are suspended only for 2001 they were not removed from this revised DPD, but highlighted as suspended.

harlequin duck field and captive studies (previously approved)

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PRINCIPAL INVESTIGATOR QUALIFICATIONS

Jim Bodkin, Research Wildlife Biologist, and team leader for coastal ecosystem in Alaska for the Alaska Biological Science Center of USGS, Biological Resources Division. He has over 20 peer-reviewed scientific publications and directs an active coastal marine research program. He has studied and published on sea otter foraging ecology and community structuring since 1988 and has been principal investigator for sea otter survey methods development. He earned a M.S. from California State Polytechnic University in 1986.

Dan Esler is a Research Wildlife Biologist with the Alaska Biological Science Center, USGS Biological Resources Division. He has conducted waterfowl research in arctic and subarctic regions of Alaska and Russia for the past 11 years. Since 1995 he has served as project leader for harlequin duck studies as part of the EVOSTC-sponsored Nearshore Vertebrate Predator project. He earned a M.S. from Texas A & M University in 1988 and is currently enrolled as a doctoral candidate at Oregon State University. He has authored over 20 peer-reviewed journal publications and numerous reports and presentations addressing research and issues in waterbird conservation.

Thomas A. Dean is President of the ecological consulting firm Coastal Resources Associates, Inc. (CRA) in Vista CA. Dr. Dean has over 20 years of experience in the study of nearshore ecosystems, and has authored over 25 publications, including several dealing with impacts of the ***Exxon Valdez*** oil spill on subtidal populations of plants and animals. He has extensive experience in long-term monitoring studies, and has played a major role in both intertidal and subtidal EVOS investigations since 1989. Dr. Dean is currently a co-principal investigator for the Nearshore Vertebrate Predator Project (NVP), and is examining the relationships between prey abundance and the recovery of sea otters, river otters, harlequin ducks, and pigeon guillemots.

Brenda Ballachey is a Research Physiologist at the Alaska Biological Science Center of USGS, Biological Resources Division. She was Project Leader for sea otter NRDA studies from 1990 through 1996, and has been involved in all aspects of post-spill research on sea otters, including the Nearshore Vertebrate Predator (NVP) project, with primary responsibilities for examining effects of residual oil on biomarkers and health of sea otters and other NVP study species. She received her M.S. in 1980 at Colorado State University, and Ph.D. in 1985 Oregon State University. She has authored or coauthored over 25 peer-reviewed publications.

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LITERATURE CITED

Babcock, M.M., G.V. Irvine, P.M. Harris, J.A. Cusick, and S.D. Rice. 1996. Persistence of oiling in mussel beds three and four years after the ***Exxon Valdez*** oil spill. Am. Fish. Soc. Symp. 18:286-297.

Ballachey, B.E., J.L. Bodkin, S. Howlin, K.A. Kloecker, D.H. Monson, A.H. Rebar and P.W. Snyder. 1999a. Appendix BIO-01 in NVP Draft Final Report (Project 950 Hematology and serum chemistry of sea otters in oiled and unoiled areas of Prince William Sound, Alaska, from 1996-98. 25-99025).

Ballachey, B.E., J.J. Stegeman, P.W. Snyder, G.M. Blundell, J.L. Bodkin, T.A. Dean, L. Duffy, D. Esler, G. Golet, S. Jewett, L. Holland-Bartels, A.H. Rebar, P.A. Seiser, and K.A. Trust. 1999b. Oil exposure and health of nearshore vertebrate predators in Prince William Sound following the ***Exxon Valdez*** oil spill. Chapter 2 ***in*** NVP Draft Final Report (Project 95025-99025).

Bodkin, J.L. and M.S. Udevitz. 1999. An aerial survey method to estimate sea otter abundance. In: Garner GW, Amstrup SC, Laake JL, Manly BJF, McDonald LL, Robertson DG (eds) Marine mammal survey and assessment methods. AA Balkema, Rotterdam, p 13-26.

Bodkin, J.L., J.A. Ames, R.J. Jameson, A.M. Johnson, and G.E. Matson. 1997. Estimating age of sea otters with cementum layers in the first premolar. J. Wild. Manage. 61(3):967-973.

Bodkin, J.L., B.E. Ballachey, T.A. Dean, S. Jewett, L. McDonald, D. Monson, C. O'Clair, and G. VanBlaricom. 1999. Recovery of sea otters in Prince William Sound following the ***Exxon Valdez*** oil spill. Chapter 3A ***in*** NVP Draft Final Report (Project 95025-99025).

Boehm, P. D., P. J. Mankiewicz, R. Hartung, J. M. Neff, D. S. Page, E. S. Gilfillan, J. E. O'Reilly, and K. R. Parker. 1996. Characterization of mussel beds with residual oil and the risk to foraging wildlife 4 years after the ***Exxon Valdez*** oil spill. Env. Toxicol. and Chem. 15:1289-1303.

Bunck, C. M., C-L. Chen, and K. H. Pollock. 1995. Robustness of survival estimates from radio-telemetry studies with uncertain relocation of individuals. J. Wildl. Manage. 59:790-794.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information theoretic approach. Springer-Verlag, New York, New York, USA.

Clarkson, P., and R.I. Goudie. 1994. Capture techniques and 1993 banding results for moulting harlequin ducks in the Strait of Georgia, B.C. Pages 11-14 in Proc. 2nd Harlequin Duck Symp., Hornby Island, B.C.

Dean, T.A., J.L. Bodkin, A.K. fukuyama, S.C. Jewett, D.H. Monson, C.E. O'Clair, and G.R. VanBlaricom. 1999. Food limitation and the recovery of sea otters in Prince William Sound. Chapter 3B ***in*** NVP Draft Final Report (Project 95025-99025).

Dean, T.A., J.L. Bodkin, S.C. Jewett, D.H. Monson and D. Jung. 2000. Changes in sea urchins and kelp following a reduction in sea otter density as a result of the ***Exxon Valdez*** oil spill. Marine Ecology Progress Series. In press.

Doak, D.F. and W.F. Morris. 1999. Detecting population-level consequences of ongoing environmental change without long-term monitoring. Ecology 80:1537-1551.

Duffy, L. K., M. K. Hecker, G. M. Blundell, and R. T. Bowyer. 1999. An analysis of the fur of river otters in Prince William Sound, Alaska: oil related hydrocarbons 8 years after the ***Exxon Valdez*** oil spill. Polar Biol. 21:56-58.

Duggins, D.O. 1980. Kelp beds and sea otters: an experimental approach. Ecology 61:447-453.

Dzus, E. H., and R. G. Clark. 1996. Effects of harness-style and abdominally implanted transmitters on survival and return rates of mallards. J. Field Ornith. 67:549-557.

Eadie, J. M., F. P. Kehoe, and T. D. Nudds. 1988. Pre-hatch and post-hatch brood amalgamation in north American Anatidae: a review of hypotheses. Can. J. Zool. 66:1709-1721.

Esler, D., T.D. Bowman, K.A. Trust, B.E. Ballachey, T.A. Dean, S. Jewett, and C. O'Clair. 1999. Harlequin duck perspective: Mechanisms of impact and potential recovery of nearshore vertebrate predators. Chapter 4 ***in*** NVP Draft Final Report (Project 95025-99025).

Esler, D., J. A. Schmutz, R. L. Jarvis, and D. M. Mulcahy. 2000a. Winter survival of adult female harlequin ducks in relation to history of contamination by the Exxon Valdez oil spill. Journal of Wildlife Management 64: in press.

Esler, D., D. M. Mulcahy, and R. L. Jarvis. 2000b. Testing assumptions for unbiased estimation of survival of radio-marked harlequin ducks. Journal of Wildlife Management 64:591-598.

Estes, J.A. and J. F. Palmisano. 1974. Sea otters: their role in structuring nearshore communities. Science 185:1058-1060.

Estes, J.A., N.S. Smith and J.F. Palmisano. 1978. Sea Otter Predation and Community Organization in the Western Aleutian Islands, Alaska. Ecology 59(4):822-833.

Estes, J. A. and D. O. Duggins. 1995. Sea otters and kelp forests in Alaska: generality and variation in a community ecological paradigm. Ecological Monographs 65(1):75-100.

Exxon Valdez Oil Spill Trustee Council. 1996. ***Exxon Valdez*** Oil Spill Restoration Plan. Draft Update on Injured Resources & Services. Anchorage.

Fischer, J. B. 1998. Feeding behavior, body condition, and oil contamination of wintering harlequin ducks at Shemya Island, Alaska. M.S. Thesis, Univ. of Mass., Amherst.

Fukuyama, A.K., G. Shigenaka and R.Z. Hoff. In press. Effects of residual ***Exxon Valdez*** oil on intertidal Prototheca staminea: mortality, growth and bioaccumulation of hydrocarbons in transplanted clams. Mar. Poll. Bull.

Galt, J. A., W. J. Lehr, and D. L. Payton. 1991. Fate and transport of the ***Exxon Valdez*** oil spill. Environ. Sci. Technol. 25:202-209.

Garrott, R.A., L.L. Eberhardt and D.M. Burns. 1993. Mortality of sea otters in Prince William Sound following the ***Exxon Valdez*** oil spill. Mar. Mam. Sci. 9:343-359.

Garshelis, D. L. 1997. Sea otter mortality estimated from carcasses collected after the Exxon Valdez oil spill. Conservation Biology. 11(4):905-916.

Goudie, R. I., and C. D. Ankney. 1986. Body size, activity budgets, and diets of sea ducks wintering in Newfoundland. Ecology 67:1475-1482.

Goudie, R. I., S. Brault, B. Conant, A. V. Kondratyev, M. R. Petersen, and K. Vermeer. 1994. The status of sea ducks in the North Pacific rim: toward their conservation and management. Proc. North Am. Wildl. and Nat. Res. Conf. 59:27-49.

Haramis, G. M., D. G. Jorde, and C. M. Bunck. 1993. Survival of hatching-year female canvasbacks wintering in Chesapeake Bay. J. Wildl. Manage. 57:763-771.

Harris, P., M. Carls, and C. Brodersen. 2000. Monitoring of oiled mussel beds in Prince William Sound (abstract). 2000 Restoration Workshop, January 18-19, 2000. EVOS Trustee Council, Anchorage.

Hayes, M.O. and J. Michel. 1999. Factors determining the long-term persistence of Exxon Valdez oil in gravel beaches. Marine Pollution Bulletin 38(2):92-101.

Holland-Bartels, L. et al. 1997. Mechanisms of impact and potential recovery of nearshore vertebrate predators. Exxon Valdez Oil spill restoration project annual report 96025. April, 1997.

Holland-Bartels, L. et al. 1998. Mechanisms of impact and potential recovery of nearshore vertebrate predators. Exxon Valdez Oil spill restoration project annual report 97025. April, 1998.

Holmes, W. N., J. Cronshaw, and J. Gorsline. 1978. Some effects of ingested petroleum on seawater-adapted ducks (***Anas platyrhynchos***). Env. Res. 17:177-190.

Holmes, W. N., J. Gorsline, and J. Cronshaw. 1979. Effects of mild cold stress on the survival of seawater-adapted mallard ducks (***Anas platyrhynchos***) maintained on food contaminated with petroleum. Env. Res. 20:425-444.

Johnson, A. M. 1987. Sea otters of Prince William Sound, Alaska. U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center, Unpublished Report. 86pp.

Kaiser, G. W., A. E. Derocher, S. Crawford, M. J. Gill, and I. A. Manley. 1995. A capture technique for marbled murrelets in coastal inlets. J. Field Ornithol. 66:321-333.

Korschgen, C. E., S. J. Maxson, and V. B. Kuechle. 1984. Evaluation of implanted radio transmitters in ducks. J. Wildl. Manage. 48:982-987.

Korschgen, C. E., K. P. Kenow, A. Gendron-Fitzpatrick, W. L. Green, and F. J. Dein. 1996. Implanting intra-abdominal radio transmitters with external whip antennas in ducks. J. Wildl. Manage. 60:132-137.

Lebreton, J. D., and J. Clobert. 1991. Bird population dynamics, management, and conservation: the role of mathematical modeling. Pages 105-125 in Perrins, C.M., J. D. Lebreton, and G. J. M. Hirons (eds.). Bird population studies: relevance to conservation and management. Oxford Univ. Press.

Limpert, R. J. 1980. Homing success of adult buffleheads to a Maryland wintering site. J. Wildl. Manage. 44:905-908.

Mather, D. D., and D. Esler. 1999. Evaluation of bursal depth as an indicator of age class of harlequin ducks. Journal of Field Ornithology 70:200-205.

Monson, D.H., D.F. Doak, B.E. Ballachey, A. Johnson, and J.L. Bodkin. 2000. Long-term impacts of the ***Exxon Valdez*** oil spill on sea otters, assessed through age-dependent mortality patterns. Proc. Nat'l. Acad. Sciences, USA 97(12):6562-6567.

Mulcahy, D. M., and D. Esler. 1999. Surgical and immediate postrelease mortality of harlequin ducks implanted with abdominal radio transmitters with percutaneous antennae. Journal of Zoo and Wildlife Medicine 30:397-401.

Mulcahy, D. M., D. Esler, and M. K. Stoskopf. 1999. Loss from harlequin ducks of abdominally implanted radio transmitters equipped with percutaneous antennas. Journal of Field Ornithology 70:244-250.

Olsen, G. H., F. J. Dein, G. M. Haramis, and D. G. Jorde. 1992. Implanting radio transmitters in wintering canvasbacks. J. Wildl. Manage. 56:325-328.

Paquette, G. A., J. H. Devries, R. B. Emery, D. W. Howerter, B. L. Joynt, and T. P. Sankowski. 1997. Effects of transmitters on reproduction and survival of wild mallards. J. Wildl. Manage. 61:953-961.

Pietz, P. J., G. L. Krapu, R. J. Greenwood, and J. T. Lokemoen. 1993. Effects of harness transmitters on behavior and reproduction of wild mallards. J. Wildl. Manage. 57:696-703.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989a. Survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53:7-15.

Pollock, K. H., S. R. Winterstein, and M. J. Conroy. 1989b. Estimation and analysis of survival distributions for radio-tagged animals. Biometrics 45:99-109.

Reidman, M.L. and J.A. Estes. 1990. The sea otter (***Enhydra lutris***): Behavior, ecology and natural history. Biological Report 90(14). U.S. Fish and Wildlife Service, Washington, D.C. 126 pp.

Robertson, G.J. 1997. Pair formation, mating system, and winter philopatry in harlequin ducks. PhD dissertation, Simon Fraser University, Vancouver, B.C.

Rotella, J. J., D. W. Howerter, T. P. Sankowski, and J. H. Devries. 1993. Nesting effort by wild mallards with 3 types of radio transmitters. J. Wildl. Manage. 57:690-695.

Savard, J-P. L., and J. McA. Eadie. 1989. Survival and breeding philopatry in Barrow's and common goldeneyes. Condor 91:198-203.

Short, J. W., and M. M. Babcock. 1996. Prespill and postspill concentrations of hydrocarbons in mussels and sediments in Prince William Sound. Am. Fish. Soc. Symp. 18:149-166.

Schmutz, J. A., R. F. Rockwell, and M. R. Petersen. 1997. Relative effects of survival and reproduction on population dynamics of emperor geese. J. Wildl. Manage. 61:191-201.

Snyder, P.W., T. Kondratyuk, B.E. Ballachey and J. Vanden Heuvel. 1999. CYP1A gene expression in sea otters (Enhydra lutris): a quantitative reverse transcriptase-polymerase chain reaction to measure CYP1A mRNA in peripheral blood mononuclear cells. Appendix BIO-02 ***in*** NVP Draft Final Report (Project 95025-99025).

Stubblefield, W. A., G. A. Hancock, W. H. Ford, and R. K. Ringer. 1995. Acute and subchronic toxicity of naturally weathered ***Exxon Valdez*** crude oil in mallards and ferrets. Env. Toxicol. and Chem. 14:1941-1950.

Trust, K. A., D. Esler**,** B. R. Woodin, and J. J. Stegeman. 2000. Cytochrome P450 1A induction in sea ducks inhabiting nearshore areas of Prince William Sound, Alaska. Marine Pollution Bulletin 40:397-403.

Udevitz, M.S., B.E. Ballachey and D.L. Bruden. 1996. A population model for sea otters in western Prince William Sound. Exxon Valdez oil spill restoration project final report (restoration project 93043-3), National Biological Service, Anchorage, AK. 34pp.

Vanden Heuvel, J.P., G.C. Clark, C.L. Thompson, Z. McCoy, C.R. Miller, G.W. Lucier, and D.A. Bell. 1993. CYP1A mRNA levels as a human exposure biomarker: use of quantitative polymerase chain reaction to measure CYP1A expression in human peripheral blood lymphocytes. Carcinogenesis 14(10):2003-2006.

Vanden Heuvel, J.P., G.C. Clark, M.C. Kohn, A.M. Tritscher, W.F. Greenlee, G.W. Lucier, and D.A. Bell. 1994. Dioxin-responsive genes: Examination of dose-response relationships using quantitative reverse transcriptase-polymerase chain reaction. Cancer Research 54:62-68.

Ward, D. H., and P. L. Flint. 1995. Effects of harness-attached transmitters on premigration and reproduction of brant. J. Wildl. Manage. 59:39-46.

White, G. C., and K. P. Burnham. 1999. Program MARK -- survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2000 - September 30, 2001

Budget Category:	Authorized FY 2000	Proposed FY 2001						
Personnel	$19.3	$169.0						
Travel	$4.6	$13.7						
Contractual	$30.8	$145.3						
Commodities	$1.2	$29.2						
Equipment	$0.6	$1.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$56.5	$358.2			Estimated FY 2002	Estimated FY 2003		
General Administration	$3.5	$35.5						
Project Total	$60.0	$393.7			$363.7	$250.0		
Full-time Equivalents (FTE)		2.8						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY01

Prepared: June 30, 2000

Project Number: 01423

Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates

Agency: DOI--USGS

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2000 - September 30, 2001

Personnel Costs:		GS/Range/	Months	Monthly		Propc
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 2
J. Bodkin (ss)	Research Wildlife Biologist	GS 13-4	1.5	7.2		1
D. Monson (ss)	Research Wildlife Biologist	GS 9-02	6.0	4.2		2
B. Ballachey (sb)	Research Physiologist	GS 12-4	3.0	7.0		2
D. Esler (hd)	Research Wildlife Biologist	GS 12	9.0	6.8		6
K. Trust (hd)	Biologist	GS 11	2.0	5.3		1
Biotechnician (hd)	Biotechnician	GS 7	8.0	3.3		2
D. Mulcahy (hd)	Veterinarian	GS 13	1.0	6.0		
Biotechnician (hd)		GS 5	3.0	2.6		
	Subtotal		33.5	42.4	0.0	
					Personnel Total	$16

Travel Costs:	Ticket	Round	Total	Daily	Propc
Description	Price	Trips	Days	Per Diem	FY 2
Anch/Cord/Anch (ss)	0.3	5	30	0.1	
Field crew/gear to Whittier (sb/sw)	0.1	10	20	0.1	
Boat transportation to Whittier (sb)	0.7	1			
Esler - Seward (hd)			25	0.1	
Field crew/gear to Whittier (molt) (hd)	0.5	1			
Field crew/gear to Whittier (winter) (hd)	0.5	1			
Meetings (1 hd, 1 so)					
				Travel Total	$1

FY01

Prepared: June 30, 2000

Project Number: 01423
Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates
Agency: DOI

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2000 - September 30, 2001

Contractual Costs:	Propo
Description	FY 2
Aircraft charter 80 hrs @ 220/hr (ss)	1
Cytochrome P450 assays, Purdue University - 30 @ $125 (sb)	
4A Linkage #1 Coastal Resources Associates (su)	
Blood assays, CCL Portland - 30 @ $60 (sb)	
Charter vessel, sea otter beach walks - 10 days @ $1200 (sw)	1
Charter vessel, sea otter capture - 15 days @ $1200 (sb)	1
Matson's Laboratory - tooth ages, 75 @ $5 (sw, sb)	
Doubly-labelled water assays - 20 @ $350 (hd)	
EROD activity - 70 @ $140 (hd)	
Charter vessel, duck capture (late summer) - 9 days @ $1500 (hd)	1
Aircraft charter - transport birds to Seward - 10 hours @ $250 (hd)	
Charter vessel (winter) - 21 days @ 1150 (hd)	2
Plumage swab analysis - 50 @ 100 (hd)	
Air charter - survival monitoring - 90 hrs @ $250 (hd)	2
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$14

Commodities Costs:	Propo
Description	FY 2
Misc field/office supplies (sb - 3.0, hd 1.0)	
Fuel (sb)	
Vet supplies (hd)	
Oxygen consumption materials (hd)	
Biosampling materials (hd)	
Kayak rental - 6 @ $150 (hd)	
Molt trap maintenance (hd)	
Captive flock maintenance - 6 months @ $450 (hd)	
Winter trap maintenance (hd)	
Radio transmitters - 50 @ $225(hd)	1
Metabolic chamber materials (hd)	
Commodities Total	$2

FY01

Prepared: June 30, 2000

Project Number: 01423
Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates
Agency: DOI--USGS

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2000 - September 30, 2001

New Equipment Purchases: Description	Number of Units	Unit Price	Propc FY 2
Equipment maintenance and repair (sb)			
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$

Existing Equipment Usage: Description	Number of Units	Inven Age

FY01

Prepared: June 30, 2000

Project Number: 01423
Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates
Agency: DOI

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2000 - September 30, 2001

Budget Category:	Authorized FY 1999	Proposed FY 2001						
Personnel		$4.0						
Travel		$0.0						
Contractual		$0.0						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$4.0			Estimated FY 2001	Estimated FY 2002		
Indirect		$3.2						
Project Total	$0.0	$7.2						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: COASTAL RESOURCES INC.
Indirect costs calculated as follows:
Indirect costs = Overhead + General and Administrative costs + Fee
Overhead = 59.5% of personnel costs
G&A = 12.85% of personnel + overhead + other direct (excluding contractual)
Fee = 4% of Total Direct + Indirect (excluding contractual)

No overhead or fees are charged on contractual costs

FY01

Prepared: June 30, 2000

Project Number: 01423
Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates
Agency: USGS --contract to Coastal Resources, Assoc.

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2000 - September 30, 2001

Personnel Costs:				Months	Monthly		Propc
	Name	Position Description		Budgeted	Costs	Overtime	FY 2
	T. Dean	Biologist		0.5	8.0		
	Indirect costs						
		Subtotal		0.5	8.0	0.0	
						Personnel Total	$

Travel Costs:		Ticket	Round	Total	Daily	Propc
	Description	Price	Trips	Days	Per Diem	FY 2
					Travel Total	$

FY01

Prepared: June 30, 2000

Project Number: 01423
Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates
Agency: USGS--CRA contract

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2000 - September 30, 2001

Contractual Costs:	Propo
Description	FY 2
Contractual Total	$

Commodities Costs:	Propo
Description	FY 2
Commodities Total	$

FY01

Prepared: June 30, 2000

Project Number: 01423
Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates
Agency: USGS--CRA contract

2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2000 - September 30, 2001

New Equipment Purchases: Description	Number of Units	Unit Price	Propc FY 2
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$

Existing Equipment Usage: Description	Number of Units	

FY01

Prepared: June 30, 2000

Project Number: 01423
Project Title: Pattern and Process of Population Change in Selected Nearshore Vertebrates
Agency: USGS--CRA contract