19.07.01 (9 of 9)

Revision 6/25/97
Approved TC 8-6-97

# Synthesis of the Toxicological Impacts on Pink Salmon

| | |
|---|---|
| Project Number: | 98329 |
| Restoration Category: | Synthesis, Integration, and Publication |
| Proposer: | Stanley D. Rice<br>NMFS, Auke Bay Laboratory<br>ABL Program Manager: Dr. Stan Rice<br>NOAA Program Manager: Bruce Wright |
| Lead Trustee Agency: | NOAA |
| Cooperating Agencies: | ADFG |
| Alaska SeaLife Center: | |
| Duration: | 1st year, 1.5-year project |
| Cost FY 98: | $25,600 |
| Cost FY 99: | $51,800 |
| Geographic Area: | Prince William Sound (field work completed) |
| Injured Resource/Service: | Pink salmon |

## ABSTRACT

This project would synthesize results of all Trustee-sponsored studies related to the toxicological damage to pink salmon. Pink Salmon were injured in 1989, and the injury persisted through 1993. The best evidence of long-term damage to any fish species following an oil spill comes from a suite of Trustee-sponsored projects. Since 1989, seven separate Trustee-sponsored projects by both ADFG and NOAA have individually advanced our understanding of the effects of the *Exxon Valdez* oilspill on pink salmon. These studies examined the past and present potential for oil exposure (Project 194), effects on egg/embryo survival (Project 191A and 191B), juvenile feeding and growth (NRDA Project 4), marine survival and straying of returning adults (Projects 076 and 209), and the possibility that effects are heritable (Project 228). We propose to draw on data from the piecemeal results from these studies to construct synthetic conclusions regarding the injury to and subsequent recovery of pink salmon. Contracted studies by EXXON have differed with the Trustee studies; their results would be compared and evaluated with the Trustee studies. A monograph for publication would be prepared, and would be the basis of a presentation at the 10th Anniversary *Exxon Valdez* Oilspill Symposium.

## INTRODUCTION

The *Exxon Valdez* oilspill caused several toxicological effects on pink salmon (*Oncorhynchus gorbuscha*), including increased mortality, reproductive impairment, and possible long-term genetic damage in pink salmon eggs and embryos that incubated in oiled intertidal sections of freshwater streams. Short-term effects were measured in 1989 and 1990, but to the surprise of the scientific community, negative impacts to developing embryos continued through 1993. The value of the pink salmon resource in Prince William Sound stimulated the gathering of the best pre-spill information; the long-term impacts stimulated a suite of field and laboratory studies to document the slow rates of recovery and to investigate mechanisms of the long-term damage. The Trustee Council funded seven separate studies to examine possible consequences to pink salmon populations. These studies by both ADFG and NOAA examined the past and present potential for oil exposure (Project 194), effects on egg/embryo survival (Project 191A and 191B), juvenile feeding and growth (NRDA Project 4), marine survival and straying of returning adults (Projects 076 and 209), and the possibility that effects are heritable (Project 228).

The pink salmon studies are the best evidence of continued long-term damage in any fish species following an oil spill. Long-term damage is a rare event that has not been documented in many species following an oil spill. The Trustee emphasis on this question has stimulated EXXON to fund independent studies of toxicological impacts on pink salmon in Prince William Sound. Some interpretations from these studies have been counter to the Trustee studies on several major issues; collectively, the two groups of studies have been controversial.

This synthesis effort would focus on the issue of long-term damage: is it real, is it significant, what are the mechanisms? Although the individual studies have greatly advanced our understanding of the effects of the *Exxon Valdez* oilspill on pink salmon, each when considered separately presents an incomplete picture of the long-term impacts. Considered together, these studies would provide a complete and comprehensive analysis of the toxicological impacts on pink salmon. Further, contradictory conclusions reached by EXXON contractors and Trustee-sponsored studies need to be reviewed and resolved.

## NEED FOR THE PROJECT

### A. Statement of Problem

Seven separate Trustee-sponsored studies and several EXXON-contracted studies have examined the toxicological impacts of the *Exxon Valdez* oilspill on pink salmon. When considered separately, the studies present an incomplete and sometimes contradictory analysis of the impacts. When analyzed together, these studies would provide the data necessary to construct a synthetic argument about the toxicological impacts on pink salmon. This project would provide the synthesis needed to link the different pieces from these studies into a comprehensive whole picture of the impacts on and recovery of pink salmon after the *Exxon Valdez* oil spill. At the 1997 Restoration Workshop, keynote speaker Dr. Kai Lee emphasized the need for syntheses such as the proposed project to bring cohesiveness to the Trustee's multi-faceted research program, and he recommended funding one synthesis project each year.

### B. Rationale/Link to Restoration

This project relates directly to the Oil Spill Restoration Plan objective to recover healthy and productive pink salmon populations to prespill abundance. The significance and causes of long-term damage would be evaluated; restoration and management strategies need this information.

### C. Location

Prince William Sound. Field work has already been completed.

## COMMUNITY INVOLVEMENT

As all field work has already been completed, only limited community involvement is envisioned for this project.

## PROJECT DESIGN

### A. Objectives

1. Synthesize results of all Trustee-sponsored studies relating to long-term toxicological injury to and recovery of pink salmon. All the major hypotheses from the various studies would be proposed and tested as part of a synthetic argument developed for this project.
2. Evaluate and incorporate into the synthesis all of the relevant EXXON funded results, and attempt to reconcile differences where possible.

### B. Methods

Data from all Trustee-sponsored studies would be collected and synthesized to test the major hypotheses about the toxicological effects of the oil spill on pink salmon. We would work together with the principal investigators to jointly review results and derive conclusions. Some of the hypotheses that would be considered include

H1: Persistent elevated egg/alevin mortality until 1994 was due to genetic damage incurred during the first incubation period after the oil spill.

H1a: Alternatively, persistent egg/alevin mortality was due to continued oil exposure until 1993.

H2: The mechanism of persistent egg/alevin mortality was reproductive impairment in adults incurred by toxicological effects during incubation.

H2a: Alternatively, the mechanism of elevated egg/alevin mortality was genetic impairment.

H3: Toxicological effects included increased egg/alevin mortality, increased marine mortality, increased straying, and decreased fecundity.

H4: Toxicological effects have disappeared at all life-history stages, and population dynamics have recovered.

### C. Cooperating Agencies, Contracts, and Other Agency Assistance

Principal investigators (Bue and Seeb) from ADFG would be asked to take part in working meetings to assist in constructing a synthesis from their individual studies. The proposed budget includes funds for 0.5 months of Bue's time in FY98 and 0.5 months of Seeb's time in FY99. No other contracts or agency assistance is required.

## SCHEDULE

### A. Measurable Project Tasks for FY 98

This project would be started in FY 98. Delaying the start to FY 99 would not allow enough time to provide a product and presentation in FY 99. Some subjects for the review are in hand now; others will be completed in FY 98. Results from the oiled stream sediment project (Project 194) will be evaluated in early FY 98, while the tag reading and data evaluation phases of the straying project (Project 076) will continue into mid FY 98 before the data and interpreted results can feed into this synthesis project.

| | |
|---|---|
| October-December 1997: | Collate data from final reports from all Trustee-sponsored studies and all appropriate EXXON studies related to toxicological impacts on pink salmon. Meet with principal investigators to evaluate the status of past studies, reports, and manuscripts; review EXXON studies; and formulate an outline and schedule for the monograph. |
| January-September 1998: | Meet with principal investigators; further develop component parts to the synthesis, including draft publication titles, conceptual outlines, and proposed journals for submission. Focus in the last half of FY 98 would be the final reports from the straying project and results of the matings of exposed fish. |
| October- December 1998 | Final draft of monograph completed; co-author reviews. |
| January 1999: | Submit synthesis monograph to journal for publication. |
| March 1999 | Present synthesis at the 10th Anniversary Symposium. |

## B. Project Milestones and Endpoints

| | |
|---|---|
| January 1998: | Data from final reports collected and tabulated. Outline of monograph prepared. Delivery to Chief Scientist list of draft publication titles, conceptual outlines, and proposed journals for publication. |
| December 1998: | Draft monograph synthesis completed and available for review. |
| January 1999: | Monograph synthesis completed and submitted for publication. |
| March 1999 | Synthesis presented at the 10th Anniversary *Exxon Valdez* Oilspill Symposium. |

## C. Completion Date

This project would be completed in Fiscal Year 1999 (March 1999).

## PUBLICATIONS AND REPORTS

This project would produce a monograph publication that would synthesize results of the separate Trustee-sponsored studies on toxicological impacts on pink salmon. It would be started in FY 98, finished in FY 99, and submitted for publication in a peer-reviewed journal in January 1999. Other publications besides the monograph may also result from this project but are not yet identified.

The synthesis would be presented at the 10th Anniversary Symposium in March 1999.

## NORMAL AGENCY MANAGEMENT

NOAA NMFS has statutory stewardship for all living marine resources; however, if the oil spill had not occurred, NOAA would not be conducting this project. NOAA NMFS proposes to make a significant contribution (as stated in the proposed budget) to the operation of this project, making it truly cooperative.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project would be coordinated with other projects conducted by ABL and ADFG. This project depends on the completion of the Trustee projects relevant to toxicological impacts on pink salmon. Several of these will be finished in FY 98 (straying, oiled stream sediments, etc.).

**PROPOSED PRINCIPAL INVESTIGATOR**

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## Cooperating Investigators (Co-authors)

**ABL**
Alex Wertheimer
Mike Murphy
Jeff Short
Ron Heintz

**ADFG**
Jim Seeb
Brian Bue

Corrected 9/3/97
Approved TC 8-6-97

# 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 | PROPOSED FY 1998 TRUSTEE AGENCIES TOTALS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | ADEC | ADF&G | ADNR | USFS | DOI | NOAA |
| | | | | $12.3 | | | | $13.3 |
| Personnel | $0.0 | $19.5 | | | | | | |
| Travel | $0.0 | $1.9 | | | | | | |
| Contractual | $0.0 | $0.0 | | | | | | |
| Commodities | $0.0 | $1.2 | | | | | | |
| Equipment | $0.0 | $0.0 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | $0.0 | $22.6 | | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| General Administration | $0.0 | $3.0 | | | | | | |
| Project Total | $0.0 | $25.6 | | $51.8 | $0.0 | $0.0 | $0.0 | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | 0.0 | 0.2 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | $0.0 | $0.0 | | $0.0 | $0.0 | $0.0 | $0.0 | |

**1998**

Prepared:

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Lead Agency: NOAA

FORM 2A
MULTI-TRUSTEE AGENCY SUMMARY

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $10.5 |
| Travel | | $0.0 |
| Contractual | | $0.0 |
| Commodities | | $1.2 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $11.7 |
| General Administration | | $1.6 |
| Project Total | $0.0 | $13.3 |
| Full-time Equivalents (FTE) | | 0.1 |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| | | | | | |

Dollar amounts are shown in thousands of dollars.

| Other Resources | | | | | | | | |
|---|---|---|---|---|---|---|---|---|

Comments:

NOAA Contributions: Stan Rice, Program Manager .5mo = $4.8K, Mike Murphy .5 mo. = $2.8K, for a total of $7.6K

**1998**

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 1998 |
| Stanley Rice | Physiologist | 14 | 0.5 | 9.6 | | 4.8 |
| Mike Murphy | Fisheries Research Biologist | 3 | 1.0 | 5.7 | | 5.7 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 1.5 | 15.3 | 0.0 | |
| | | | | | **Personnel Total** | $10.5 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $0.0 |

**1998**

Prepared: 3 of 9

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

9/3/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed FY 1998 |
|---|---|
| Description | |
| | |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $0.0 |

| **Commodities Costs:** | Proposed FY 1998 |
|---|---|
| Description | |
| computer repairs, maintenance, and software upgrades | 1.2 |
| **Commodities Total** | $1.2 |

**1998**

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3B
Contractual & Commodities DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| New Equipment Purchases: Description | Number of Units | Unit Price | Proposed FY 1998 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

| Existing Equipment Usage: Description | Number of Units | Inventory Agency |
|---|---|---|
| | | |

**1998**

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3B
Equipment
DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| Personnel | | $9.0 | | | | | | |
| Travel | | $1.9 | | | | | | |
| Contractual | | $0.0 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | | | | | | |
| Subtotal | $0.0 | $10.9 | | | | | | |
| General Administration | | $1.4 | | | | | | |
| Project Total | $0.0 | $12.3 | | | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.1 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

ADFG Contribution: Brian Bue .5 mo. = $4.5K, Jim Seeb .5 mo. = $4.5K, for a total contribution of $9.0K

**1998**

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 1998 |
| Brian Bue | Fisheries Research Biologist | 18 | 0.5 | 9.0 | | 4.5 |
| Jim Seeb | Fisheries Research Biologist | 18 | 0.5 | 9.0 | | 4.5 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 1.0 | 18.0 | 0.0 | |
| | | | | | **Personnel Total** | $9.0 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| Anchorage to Juneau for work meeting with Rice, Murphy, Bue, and Seeb | 0.4 | 2 | 4 | 0.2 | 1.6 |
| car rental for above | | | | | 0.3 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $1.9 |

**1998**

Prepared: 7 of 9

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3B
Personnel
& Travel
DETAIL

9/3/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed FY 1998 |
|---|---|
| Description | |
| | |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $0.0 |

| **Commodities Costs:** | Proposed FY 1998 |
|---|---|
| Description | |
| | |
| **Commodities Total** | $0.0 |

**1998**

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3B
Contractual & Commodities DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 1998 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

| **Existing Equipment Usage:** Description | Number of Units | Inventory Agency |
|---|---|---|
| | | |

**1998**

Prepared: 9 of 9

Project Number: 98329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3B
Equipment
DETAIL

9/3/97

Approved TC 8-6-97

# Mass-Balance Model of Trophic Fluxes in Prince William Sound

| | |
|---|---|
| Project Number: | 98330-BAA |
| Restoration Category: | Research |
| Proposer: | D. Pauly/UBC, S. Pimm/U. Tenn |
| Lead Trustee Agency: | NOAA |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | No |
| New or Continued: | New |
| Duration: | 1st yr.<br>2 yr. project |
| Cost FY 98: | $179.8 |
| Cost FY 99: | $185.5 |
| Cost FY 2000: | $0.0 |
| Cost FY 01: | $0.0 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | All |


## ABSTRACT

This project would construct, validate, and disseminate two models of trophic interactions among the organisms of Prince William Sound, as required to synthesize the vast amount of information gathered before and after the oil spill, and to evaluate its impact at the ecosystem level. Project components are: (1) an initial workshop devoted to model specification by researchers from the Gulf of Alaska region, (2) an extended study by project staff, and (3) a dissemination phase, in year two, consisting of a training workshop for potential users of the software implementing the model, and the production of a CD-ROM for the public domain, incorporating an interactive graphic version of the software, and an extensive database on the biology and local/traditional knowledge on fishes of Prince William Sound.

## INTRODUCTION

The project proposed here is a response to the fact, noted by the Trustee Council, that "the restoration program has reached a stage where it is appropriate to integrate and synthesize what is being learned from different research and monitoring projects" and thus to enable the Trustee Council "to view the effects of the oil spill and the long-term restoration and management of injured resources and services from an ecosystem-level perspective" (EVOS Trustee Council, 1996, p. 53). The approach proposed to achieve this is based on the reasoning that biological production (expressed as energy or carbon) in a given ecosystem must be either exported or consumed locally, and that the biological production of a given group that is not exported must be equal to that which is consumed by the other groups in the system. Such simple mass-balance constraints, when explicitly formulated for each of the major species or functional groups of an ecosystem, can be used to validate (or correct) independent standing stock and flux estimates, and to rapidly construct thermodynamically "possible" trophic models of ecosystems. Models of this sort can then be used to draw numerous inferences on the structure of ecosystems, and the interactions among their components (Christensen and Pauly 1992a, b, 1995, Pauly and Christensen 1993, Pauly and Christensen 1995).

The project proposed here is to construct a trophic model, based on the well-documented ECOPATH software, used from both the above-cited contributions and the models of diverse ecosystems presented by various authors in Christensen and Pauly (1996). The structure of the model will be based on inputs by colleagues studying the various groups in PWS and adjacent areas with EVOS funding, and other experts to be contacted as appropriate. We will formulate two simple, large-scale trophic models of, and uniting, the communities of the APEX, SEA, and NVP projects. Using their published data, data from the literature and the results of a workshop, we seek a broad synthesis of the larger Prince William Sound and Gulf of Alaska ecosystems and the complex changes within them. This broad participation, and the consensus-seeking process used for model specification, should ensure that the product will be perceived as state-of-the-art within the EVOS community.

The general question to be examined with a mass balance model is how effects of the oil spill propagate throughout the food web. When and where else in the food web will the consequences of change in one (or more) species be manifested (Vanni 1987a, 1987b)? Counterintuituve indirect effects may appear several trophic linkages away from their cause (Abrams 1992). In the Bering Sea, for example, the large pollock fishery has caused the decline of pollock-eating sea-lions, murres, and kittiwakes, but more distantly, caused an increase in auklets -species that feed on the plankton on which the pollock feed (Springer 1992). To study such indirect effects, the system of linear equations underlying mass-balance models can be reexpressed as a system of coupled differential equations using a new module (ECOSIM) of the ECOPATH software (Walters et al., in press). This allows, once mass-balance has been established, the rapid construction of a simulation model for any ecosystem. Thus, the proposed project will also generate a simulation model of trophic interactions in PWS and adjacent waters, allowing e.g. "preliminary examination of the potential impacts of large-scale perturbations such as the major decline in the population of Pacific herring." (EVOS Trustee Council, 1996, p.53.)

To ensure the acceptability and wide dissemination of the model , among the public as well as among managers, in year two the product will be released in the context of a training/evaluation

workshop, and also made available for distribution by the Trustee Council to interested organizations and institutions, including schools, in form of a CD-ROM that will also contain a database with local /traditional knowledge and scientific information on all fishes of PWS, and of Alaska. This will comprise a locally-enriched, customized version of "FishBase", the global, computerized encyclopedia of fishes. (see MacCall and May 1995).

## NEED FOR THE PROJECT

### A. Statement of Problem

"Research sponsored by the Trustee Council has produced many data sets on the distribution, abundance and productivity of many species and ecological communities of the northern Gulf of Alaska and Price William Sound. These data need to be integrated in a simple model to benefit long-term resource Management." Also , "the restoration program will increasingly focus on an integrated, ecological approach. To that end, The Trustee Council has identified a possible need for a simple cost-effective ecosystem model" (EVOS Trustee Council, 1996, p.53.)

In a large, multi-faceted research program it is often easy to lose track of the relevance and position of each project in the overall picture that is being created. Several EVOS-funded projects, notably APEX, NVP, and SEA, are devoted to the biology and ecology of distinct groups of organisms, sometimes including their prey, and /or their predators. A straightforward approach to link these organisms, and hence the projects that study them, is through the fact that all organisms, in natural ecosystems, are connected through feeding links. Indeed, trophic interactions are among the most significant links between organisms, especially when considering how to restore a damaged environment and to monitor the potential flows of toxic residues through that environment. Given that indirect effects are important and ubiquitous, we may not fully understand the complex changes occurring in the Prince William Sound and Gulf of Alaska ecosystems unless we recognize their consequences. The complete list of potential questions must come from our working closely with the range of scientist and affected parties. Nonetheless, we can list possibilities where our models might be useful for all the APEX, SEA, and NVP communities.

1. What will be the consequences of loading hatchery raised salmon into the system given the complex interactions between juvenile salmon, large copepods and pollock?
2. What other components of the ecosystem will the decline of Pacific herring stocks affect? What contribution does this make to the declines of marine bird and mammal populations?
3. In what species groups will the consequences of fishing become apparent? Is there likely a strong connection between fishing, marine bird, and marine mammal populations?
4. What are the consequences of changes in harbor seal populations?
5. Should we expect sea-otters, harlequin ducks, guillemots and other oil-affected near-shore species to recover in the near-term, given the observed ecosystem changes?
6. How should the change from an ecosystem dominated by shrimp to one dominated by pollock and cod affect seabirds, marine mammals, and other species groups?
7. How do changes in one ecosystem -- say, the near-shore – affect processes in other ecosystems?

## B. Rationale/Link to Restoration

A rapidly achieved overview of the trophic structure of PWS and adjacent waters and the relationships between the different species and groups that inhabit the area will assist both individual EVOS projects and planning future policy. For example, an ECOPATH model of PWS will be able to indicate whether there has been, since the oil spill, a shift in the trophic structure that is hindering the recovery of seabirds and marine mammals. As well, a quantitative analysis of the relationships between seabird foraging and hatchery-released fish will help to identify problems in the restocking program. The versatility of the ECOPATH system allows it to produce a fast and cost-effective overview of any part of the system. The basic idea of this project is that the use of a mass balance model such as ECOPATH will allow easy identification of areas of trophic flux that will be of great interest to all workers involved in the restoration project. The initial workshop will allow the input of data and ideas from a range of people from different projects, while the subsequent analysis of the output from the model will provide feedback and ideas to the researchers in the individual projects.

Further, the outputs from the ECOSIM module of ECOPATH will allow rapid exploration of the predicted consequences of various intervention or events (e.g. restocking, selective harvesting, or changes in some physical forcing functions). In particular, clues discerning which species contribute most to long-term stability of the communities will aid resource managers in making decisions that affect the development of these communities. For example, the successful and sustainable management of the herring and salmon populations depends on a model of the food webs joining the different communities.The final evaluation meeting will provide a forum for validating and teaching the use of this relatively simple model for evaluating management options for PWS.

Production of interactive software displaying temporal changes resulting from the direct or indirect effects of management interventions will allow for novel approaches for explaining basic ecological principles, and species interactions in PWS to the general public, schoolchildren and various special interest groups. The public impact of the proposed project will be strengthened by embedding its main output, the ECOPATH/ECOSIM model of PWS, into a database on the fish of the PWS region, i.e., a version of the computerized encyclopedia of fishes known as FishBase, whose coverage of Alaskan fishes will be enriched by incorporation of as much biological and local/traditional knowledge as can be straightforwardly extracted from published sources.

## C. Location

The models to be constructed will refer to PWS in the narrow sense. The proposed workshops, one for model specification, and one, in year two, for product release, (see above) will be held at locations which will minimize participants' travel and other costs, presumably in Anchorage. The biological and local/traditional knowledge to be incorporated into FishBase will pertain to the wider PWS region, i.e., include information from outside PWS proper. Thus, the benefits will accrue across the areas of the Gulf of Alaska and Prince William Sound that harbor APEX, SEA, or NVP communities.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Trophic linkages derived from the experience of fishers and hunters will be considered when specifying the PWS model if citeable sources can be found documenting this experience. Similarly, all local/traditional knowledge on the fishes of the PWS region to be included in FishBase will rely on published sources, as the project does not include a field component. However, care will be taken to enable access to all scientific information on the fishes of the PWS region through local common names, in as many aboriginal languages as possible, using the routines newly incorporated into FishBase for such coverage of common names. A project extension phase to deepen this specific aspect of the database, and which would include a field work component, may eventually be proposed, given an expression of interest by the Trustee Council.

## PROJECT DESIGN

### A Objectives

The project objectives for FY 97 will be:

1. Prepare and hold a one-week model specification workshop;
2. Build a food web model of the interactions of the APEX community members.
3. Build a food web model of the interactions of the NVP community members.
4. Build a food web model of the interactions of the SEA community members.
5. Integrate the three food webs into two, large-scale models of the interactions of the communities.
6. Interact with experts and modify ECOPATH mass-balance model until consensus on trophic interactions in PWS and adjacent waters is reached;

For FY 98, the project objectives will be:

7. Enter biological information, local names in local languages, and local knowledge (sofar published) on PWS region fishes and other Alaskan fishes into FishBase.
8. Modify ECOPATH such that seasonal changes are explicitly considered when establishing mass balance;
9. Link the ECOSIM module of the PWS model with an existing model of PWS capable of predicting primary production, and thus drive the trophic interactions in ECOSIM;
10. Prepare a CD-ROM with ECOPATH/ECOSIM model(s) of PWS, and a database on the fishes of the PWS region;
11. Prepare and hold a one-week workshop to present and disseminate the final product (in 7), and teach its use.

Additionally, throughout the duration of the project, and beyond, every opportunity will be taken to present the project and its products, especially at conferences and in the primary literature.

## B Methods

The models proposed here are extremely simple and yet they account for uncertainties. One approach of past model building has been to build more complex, detailed models, and to demand more data to parameterize them. We are repelled, rather than seduced by this process. As field ecologists we know that the simplest model parameter may be enormously difficult to obtain. As theoreticians, we see a more practicable alternative. Nature is uncertain: a parameter value, here, this week will not be the same as there, next week. Any model that aims to yield insight of use to managers must be robust to these uncertainties (Ludwig et al. 1993). Based on work of Dr. J.J. Polovina (1984), of the US National Marine Fisheries Service, Drs. D. Pauly and Villy Christensen, then both at the International Center for Living Aquatic Resources Management (ICLARM) in Manila, Philippines, developed an approach, implemented as a well-documented software for personal computers, which allows for the rapid construction and verification of mass-balance models of ecosystems (Christensen and Pauly 1992 a, b). The steps involved in the construction of the two models are:

(i) Identification of the area and period(s) for which models are to be constructed;
(ii) Definition of the functional groups (i.e., "boxes") to be included;
(iii) Entry of a diet matrix, expressing the fraction that each "box" in the model represents in the diet of its consumers (with uncertainty being accommodated by wide intervals about the entries);
(iv) Entry of food consumption rate, of production/biomass ratio or of biomass, and of fisheries catches, if any, for each box (with uncertainty again being accommodated by wide intervals about the entries);
(v) Balance the model using either a Monte Carlo approach (i.e., randomly selecting entries from input distributions and selecting model realization based on parameters closest to central values) or modify entries (iii & iv) until input = output for each box;
(vi) Compare model outputs (network characteristics, estimated trophic levels and other features of each box) with estimates for the same area during another period, and or with outputs of the same model type from other, similar areas, etc., and use result of comparison to ensure that inputs are credible;
(vii) Use model balanced in (vi) to generate simulation model via the ECOSIM module of ECOPATH, run same and test its sensitivity to various perturbations;
(viii) Use results in (vii) to refine mass balance model if required, then output different runs

These steps can be implemented easily when basic parameter estimates exist (as in the case of PWS and adjacent waters), and numerous, well-documented examples already exist of ECOPATH applications to aquatic ecosystems, ranging from aquaculture ponds and flooded rice paddies to shelf systems (see Pauly and Christensen 1993, and contributions in Christensen and Pauly 1993), notably the North Sea, and versions of three systems relatively close and similar to PWS, Georgia, Strait, Vancouver Island and the Alaska Gyre, constructed during a one-week workshop similar to the one proposed here, and held in November 1995 (Pauly and Christensen, 1996). Each participant will cover a functional group and its associated fluxes: phytoplankton and primary production, marine bacteria and their consumption of detritus, zooplankton and secondary production, major fish species and their fisheries, marine mammals and birds and their food consumption. Rate and biomass estimates will be standardized for the PWS and adjacent waters and for two different periods (pre spill and post spill). Once parameterized, the problem becomes one of understanding the consequence of the change in density of one species to the change in

density of other species in the food web. Technically, the issue is one of resistance (Pimm 1984, 1991): the extent to which different components resist changes elsewhere in the food web. Our simple models allow calculation of simple effects. How will the change in, say, fishing effort affect the abundance of different species of seabird, or which species will be most affected by the change in seal or otter numbers? The technical aspects of this process are familiar (Pimm 1991). For a given parameterization of a particular food web, we can "tweak" the species known to have declined and look where (and, importantly how quickly) the consequent changes will be manifest. The simplicity of our models makes this a rapid and so highly repeatable process. Ongoing analysis of data and model updating will also provide a means of incorporating new information from the various EVOS projects and also a route for identification of possible gaps in current research. Thus, the work of project staff can be tailored to requirements identified during the specification workshop.

### C Cooperating Agencies, Contracts and Other Agency Assistance

The PIs and other investigators of all EVOS-funded projects devoted to studying PWS and Gulf of Alaska organisms will be contacted (preferably through the Trustee Council), and invited to participate, along with other experts, in the model specification workshop, and the subsequent validation process. Personal contacts were established during the January 1996 Restoration Workshop which will facilitate this; however commitments were not sought at this stage, as they were assumed to be easy to obtain one the project has been approved..

In year two, the Fisheries Centre, UBC, will subcontract item 4 under "Objectives" (see above) to the FishBase Project of the (non-profit) International Center for Living Aquatic Resources Management (ICLARM), Manila Philippines, both because data encoding in the Philippines is extremely cost-effective, and more importantly, because data entry for FishBase is done only centrally, by FishBase project staff. (Note that creating local alternative to FishBase would not be cost effective, due to the major international investment that has already gone into FishBase). Additionally, in year two, the Fisheries Centre will subcontract item 7 to an off-campus consultant who is an affiliate of the Fisheries Centre and has experience with fisheries related projects. All other items will be handled by Fisheries Center faculty, or affiliates, or project staff to be hired by the Fisheries Centre. The work done by Stuart L. Pimm will be done as a subcontract to him.

## SCHEDULE

### A Measurable Project tasks for FY 98 (October 1, 1997 - September 30, 1998)

| | |
|---|---|
| 1) Oct. 1 - Dec. 31: | We will first conduct an extensive literature search; we need to gain a broad understanding of the naturally occurring marine food webs. We will be gathering data on biomasses, feeding rates, and other parameters from published food webs, so that we have an idea of what ranges of values are acceptable for these models. We will also be investigating the structural patterns of related published food webs. |
| 2) Jan. 22-25: | Pauly and Pimm attend the Annual Restoration workshop. In the week before this meeting we will hold the ECOPATH meeting. |

| | |
|---|---|
| 3) Mar. - Sep. 30: | Refine model initially specified during workshop, with emphasis on data from EVOS projects, and their uncertainty, and present model at scientific conferences (incl. at the 1998 Restoration Workshop), and in the primary literature. |

**B Project Milestones and Endpoints**

FY 97 Milestones (besides required annual reports):

| | |
|---|---|
| Jan. 1998: | Presentation of concept at Annual Restoration Workshop; |
| Feb. 1998: | Holding of PWS Model Specification Workshop; |
| Apr. 1998: | Publication of workshop report; |
| Jun. 1998: | Submission of two scientific papers documenting key features and behavior of trophic mass-balance models of PWS and adjacent waters; |

FY 98 Milestones (besides required annual reports):

| | |
|---|---|
| Nov. 1998: | Incorporation into ECOPATH of a routine explicitly accounting for seasonal oscillations, and submission of scientific paper documenting this feature, illustrated through a PWS mass-balance model accounting for seasonal oscillations of all input parameters; . |
| Jan. 1999: | Presentation at Annual Restoration Workshop of an ECOSIM-based trophic simulation model, with primary production driven by a physical model of PWS. |
| Mar./Apr. 1999: | Holding of final workshop; |
| Aug. 1999: | Release of CD-ROM with ECOPATH/ECOSIM models of PWS and adjacent waters and database on scientific and local knowledge of Alaskan fishes, for distribution by Trustee Council. |
| Aug. 1999: | Submission to Trustee Council of first FishBase CD-ROM enriched with information on PWS fishes. |

**C Completion Dates**

As for "Milestones;" project will be completed on August 1999 (FY 99)

**PUBLICATIONS AND REPORTS**

The above project milestones identify anticipated publications and reports; more details cannot be provided at present. The publication record of the Principal Investigators (see attached resumes) are invoked here: we will document and publish our work in the primary literature.

## PROFESSIONAL CONFERENCES

The principal investigator are often invited to present keynotes at various conferences (see resumes) and will use the opportunities this provides to present the results of the proposed work, and its EVOS science context.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORTS

The aim of the proposed work is to synthesize data from projects funded by the Trustee council (see above under "NEED FOR THE PROJECT")

## PROPOSED PRINCIPAL INVESTIGATORS

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## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

Approved TC 8-6-97

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $168.0 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $168.0 |
| General Administration | | $11.8 |
| Project Total | $0.0 | $179.8 |
| Full-time Equivalents (FTE) | | 0.0 |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 |
|---|---|---|---|
| | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

**1998**

Prepared: 1 of 1

Project Number: 98330-BAA
Project Title: Mass Balance Model of Trophic Fluxes in PWS
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

8/28/97

Revision 6-4-1

# 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $92,550.0 |
| Travel | | $30,880.0 |
| Contractual | | $2,800.0 |
| Commodities | | $3,710.0 |
| Equipment | | $9,680.0 |
| Subtotal | $0.0 | $139,620.0 |
| Indirect | | $28,382.6 |
| Project Total | $0.0 | $168,002.6 |
| Full-time Equivalents (FTE) | | 29.5 |
| Other Resources | | |

| LONG RANGE FUNDING REQUIREMENTS | | | | |
|---|---|---|---|---|
| | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 |
| | $173,403.6 | $0.0 | $0.0 | $0.0 |

Dollar amounts are shown in thousands of dollars.

Comments: Indirect costs are for UBC Fisheries Centre, standard UBC contract overheads and cover general sevrices, adminsrtation, space and buildings, computer facilities, basic office supplies and communications. They are calculated at the standard UBC contract rates for ' non-commercial government and NGOs' of 30% of the cost of personnel and 2% or travel costs. Postdoctoral salary includes benefits according to standard UBC employment conditions.

**1998**

Project Number: ~~800~~ 98330-BAA
Project Title: A Mass Balance Model of the Trophic Fluxes in PWS
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4A
Non-Trustee
SUMMARY

Prepared: 04/07/1997



6/17/97

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 1998 |
| Dr Daniel Pauly | PI - UBC Fisheries Centre | | 2.0 | 7500.0 | | 15,000.0 |
| Dr Stuart Pimm | PI | | 2.0 | 7500.0 | | 15,000.0 |
| Dr Carl Walters | numerical modeller - UBC Fisheries Centre | | 0.5 | 7500.0 | | 3,750.0 |
| Dr Tony Pitcher | ecologist, project manager, UBC -FC | | 0.5 | 7500.0 | | 3,750.0 |
| Dr Villy Christensen | ecopath model consultant | | 0.5 | 7500.0 | | 3,750.0 |
| Lisa Manne | Graduate student, Pimm | | 12.0 | 1775.0 | | 21,300.0 |
| (to be appointed) | Postdoc Research Asst, - UBC-FC | | 12.0 | 2500.0 | | 30,000.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 29.5 | 41775.0 | 0.0 | |
| | | | | | Personnel Total | $92,550.0 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| UBC PI, modeller + postdoc to ann'l EVOS mtg + 1st Ecopath wksp | 850.0 | 3 | 24 | 130.0 | 5,670.0 |
| Dr Christensen from Demnark to 1st Ecopath wksp | 1700.0 | 1 | 8 | 130.0 | 2,740.0 |
| 5 US participants at model workshop - non-Alaskans | 1000.0 | 5 | 20 | 130.0 | 7,600.0 |
| PI Pimm and student Manne to annual EVOS meeting | 1100.0 | 2 | 16 | 130.0 | 4,280.0 |
| PI Pimm and student Manne to Vancouver | 1100.0 | 2 | 8 | 130.0 | 3,240.0 |
| UBC PI, modeller and postdoc to ecopath tech'l review | 850.0 | 3 | 12 | 130.0 | 4,110.0 |
| PI Pimm and student Manne to ecopath tech'l review | 1100.0 | 2 | 8 | 130.0 | 3,240.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | Travel Total | $30,880.0 |

1998

Project Number: 300
Project Title: A Mass Balance Model of the Trophic Fluxes in PWS
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4B
Personnel
& Travel
DETAIL

Prepared: 04/07/1997

1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

| Contractual Costs: | Proposed |
|---|---|
| Description | FY 1998 |
| Report draft, editing, binding and delivery | 2,800.0 |
| **Contractual Total** | $2,800.0 |

| Commodities Costs: | Proposed |
|---|---|
| Description | FY 1998 |
| computer supplies | 1,100.0 |
| offic and secretarial | 860.0 |
| LAN charges | 1,000.0 |
| Fax, phone, postage | 750.0 |
| **Commodities Total** | $3,710.0 |

1998

Project Number: 300
Project Title: A Mass Balance Model of the Trophic Fluxes in PWS
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4B
Contractual & Commodities DETAIL

Prepared: 04/07/1997



6/17/97

| New Equipment Purchases: Description | Number of Units | Unit Price | Proposed FY 1998 |
|---|---|---|---|
| 2 Notebook computers (2 PIs, Postdoc and Grad student) for running ECOPATH | 2 | 4000.0 | 8,000.0 |
| proprietary software | 2 | 560.0 | 1,120.0 |
| ZIP mass-storage drive for data | 2 | 280.0 | 560.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | New Equipment Total | $9,680.0 |

| Existing Equipment Usage: Description | Number of Units |
|---|---|
| | |

1998

Project Number: 300
Project Title: A Mass Balance Model of the Trophic Fluxes in PWS
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4B
Equipment
DETAIL

Revised 11/6/97
Approved TC 12-18-97

# Survival of Adult Murres and Kittiwakes in Relation to Forage Fish Abundance

| | |
|---|---|
| Project Number: | 98338 |
| Restoration Category: | Research |
| Proposer: | J. Piatt/USGS |
| Lead Trustee Agency: | DOI |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | No |
| New or Continued: | New |
| Duration: | 1st yr.<br>3 yr. project |
| Cost FY 98: | $56.2 |
| Cost FY 99: | $57.9 |
| Cost FY 2000: | $45.0 |
| Cost FY 01: | $0.0 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Cook Inlet, Gulf of Alaska |
| Injured Resource/Service: | Common murre |


## ABSTRACT

Some seabird populations damaged by the spill continue to decline or are not recovering. In order to understand the ultimate cause of seabird population fluctuations, productivity, recruitment, and adult survival must be measured. Current APEX (Project /163) studies are focused on measuring productivity only. Recruitment measurement demands an unrealistic study duration. This project will augment current studies in lower Cook Inlet that relate breeding success and foraging effort to fluctuations in forage fish density by using banding and resighting to quantify the survival of adult common murres and black-legged kittiwakes.

## INTRODUCTION

Some seabird populations in the Gulf of Alaska have undergone marked fluctuations during the past few decades (Hatch and Piatt 1995; Piatt and Anderson 1996), including periods of decline or non-recovery. Ultimately, the ability of injured or declining seabird populations to recover depends on: 1) breeding success, or productivity; 2) fledgling survival and subsequent recruitment; and 3) overwinter survival of adults (Harris and Wanless 1988). Without concurrent measurement of at least two of these three parameters, it is difficult to determine which factor is limiting a population's recovery.

Mechanisms that regulate seabird populations by influencing productivity, recruitment, and adult survival are poorly understood, but food supply is clearly important (Cairns 1992). Studies sponsored by the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) in 1995 and 1996 (APEX, project no. 98163) have shown linkages between food supply and population fluctuations. Exactly which parameters of reproductive strategy are driven by food supply, and so drive population fluctuations, remain unclear. To date, APEX has focused on forage fish availability and its relationship to productivity.

We propose to determine the overwinter survival of adult common murres (*Uria aalge*) and black-legged kittiwakes (*Rissa tridactyla*) using established banding and resighting techniques at two of the colonies (Fig. 1) currently being investigated by APEX (Project 98163M). Results of 1996 work show clear differences in prey availability between the two colonies, with forage fish being scarce around Chisik Island and abundant around Gull Island. Both seabird species must work significantly harder at Chisik to provide food to their chicks (Fig. 2). This difference appears to be manifested in sharply reduced kittiwake production at Chisik Island (Fig. 2). Observing that kittiwake populations have been steadily declining at Chisik while increasing at Gull (Fig. 3), one might be tempted to conclude that weak productivity and recruitment are driving the Chisik kittiwake population declines. However, while murres (at least in recent years) have been similarly productive at Chisik and Gull (Fig. 2; J.F. Piatt unpubl. 1997 data), the Chisik Island murre population has historically declined at an even greater rate than the kittiwake population.

From these data we conclude that the murre population decline at Chisik Island and concurrent increase at Gull Island may be attributable to differences in adult survival rates. Measurement of survival rates, in coordination with APEX's focus on food supply and colony productivity, should help to more completely resolve the mechanisms underlying seabird population fluctuations, particularly for those species such as murres that are able to buffer against periods of food shortage by increasing foraging effort (Burger and Piatt 1990; Irons 1992).

Our proposed research will measure adult survival of both murres and kittiwakes at Chisik and Gull Islands. We will use conventional banding/resighting methods to establish both species' adult survival rates. We will also use radio telemetry to measure activity budgets of breeding murres at each colony, in order to quantify "foraging stress" integrated throughout the breeding

season. Foraging stress from breeding effort is probably a major contributor to adult overwinter mortality (Golet et al. 1998). Working in collaboration with the CISeaFFS component of the APEX project, we will compare survival between colonies in relation to foraging stress, breeding success, and forage fish abundance. The proposed work will enhance our understanding of the relationships among survival, reproduction, and foraging in kittiwakes and murres in lower Cook Inlet. In a broader context, our research will clarify the mechanisms and limiting parameters underlying natural population declines or the failure of injured populations to recover.

## NEED FOR THE PROJECT

### A. Statement of the Problem

Research has provided few clear examples of how seabird population biology is affected by changes in prey availability (Hunt et al. 1991). Consequently, it has been difficult to understand the non-recovery of some EVOS-damaged seabird populations because natural changes in forage fish stocks may have also contributed to their decline. The picture is further complicated by our inability to pinpoint which aspect of population biology ultimately drives population fluctuations. To determine the cause of population declines or non-recovery, the population's productivity, recruitment, and adult survival should be measured concurrent with evaluation of available food supply (Cairns 1992).

Current EVOSTC-funded work (APEX, project no. 96163M) is measuring productivity and foraging differences of seabirds in response to fluctuating prey availability. Preliminary results from research conducted in lower Cook Inlet show some correspondence between productivity and forage fish availability to breeders. There is no correspondence, however, in species such as the murre which are able to increase foraging effort in response to decreasing forage fish abundance (Burger and Piatt 1990). Differences in recruitment and/or adult survival are thus implicated as important determinants of population fluctuations. Yet their relative importance has not yet been established by EVOSTC researchers, despite past work which has shown that variation in either recruitment or adult survival could obscure or even offset population fluctuations apparently driven by productivity differences (Hudson 1985).

Since murres and kittiwakes do not commence breeding until they are several years old (Hudson 1985; Aebischer and Coulson 1990), it is not feasible to measure recruitment in Cook Inlet seabird populations within the time frame required by EVOSTC funding. Measurement of adult overwinter survival has not yet been studied within a complete ecological framework, and has been identified by APEX reviewers as an important topic for expanded research in pursuit of understanding population fluctuations and recovery.

## B. Rationale

Population changes are continually being driven by natural ecosystem changes, and are occasionally driven by anthropogenic perturbations such as the *Exxon Valdez* oil spill. In order to separate natural population fluctuations from anthropogenic population changes, we must have a complete understanding not only of the factors which drive population changes (e.g. change in prey availability) but also of the population biology parameter which is most altered by those driving forces. Chick productivity in relation to varying prey availability is currently being studied, but cannot explain all observed population trends. It is not feasible to measure chick survival and recruitment. Therefore, to assess the potential for recovery of seabirds affected by the *Exxon Valdez* oil spill by pinpointing the cause of population trends, a study of adult survival and its relationship to prey availability is required.

In collaboration with the ecosystem-based study of seabird foraging conditions and breeding biology currently being conducted by APEX in lower Cook Inlet (project no. 98163M), we have a unique opportunity to assess not only the role of adult survival in seabird population fluctuations, but also the suspected linkage between foraging effort during the breeding season and adult overwinter survival. By choosing species with different long-term breeding strategies (kittiwakes maintain investment in reproduction at relatively constant [high] levels despite variation in food supply; murres adjust reproductive effort in relation to prey availability by altering buffer or "loafing" time) we will address questions raised by ongoing APEX work that shows linkage between prey availability and population fluctuation in some species (kittiwake) but only implies a linkage in others (murre). Refined understanding of foraging effort in relation to food supply will further our understanding of the costs of breeding in murres and kittiwakes. Stress induced by increased foraging effort in response to poor foraging conditions may explain variation in adult survival.

## C. Location

The proposed research will be undertaken in lower Cook Inlet, Alaska. The project's benefits will be realized throughout the EVOS area, in the form of enhanced understanding of seabird population trends and recovery mechanisms. Homer, Alaska is the only community that may be directly affected by the proposed research (as detailed below).

# COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Gull Island in Kachemak Bay is owned by the Seldovia Native Association (SNA). Limited subsistence use occurs during summer, with occasional egging and harvesting of juvenile birds (Fred Elvsaas, pers. comm.). It is also a major tourist attraction for visitors to Homer. Permission to work on and around the island has been obtained under the provision that annual reports of findings be made available to the SNA. We also plan to inform the local tour boat operators about our activities so that our presence at the island can be explained to visiting

tourists. Chisik Island is managed by the Alaska Maritime National Wildlife Refuge, and we will employ charter vessels from Homer to support field work there. Chisik Island supports a small, seasonal fishing community and we will inform the summer residents about the nature and purpose of our activities. Every attempt will be made to include local residents in the pool of applicants considered for volunteer positions related to the project. Whenever possible, equipment and other resources will be acquired locally in the Homer area. Traditional and local ecological knowledge will be sought from fishermen and other residents, particularly on the topic of seabird population trends and foraging patterns.

## PROJECT DESIGN

### A. Objectives

Survival Component

1. To determine adult common murre and black-legged kittiwake overwinter survival rates, using conventional banding and resighting methods.

2. To relate differences in common murre and black-legged kittiwake overwinter survival to differences in prey availability and foraging effort during the breeding season.

Foraging Component

3. To characterize the daily and seasonal activity patterns of breeding common murres and black-legged kittiwakes using radio telemetry, and examine their relationship to prey availability.

### B. Background

To test our primary hypothesis- that adult common murre and black-legged kittiwake overwinter survival is related to prey availability and foraging stress during summer- we need to obtain measures of overwinter survival concurrent with measures of prey abundance and distribution. Data on prey (forage fish) abundance and distribution will be obtained via coordinated efforts with EVOSTC-funded projects 96163M (APEX) and 97306 (Sand Lance Ecology).

We will conduct the proposed research at Chisik and Gull Islands, lower Cook Inlet (Fig. 1). Chisik Island has relatively low prey availability within typical murre/kittiwake foraging ranges, while Gull Island has high prey availability (Piatt unpubl. data). The Chisik Island populations of both murres and kittiwakes have shown steady declines over the past two decades, in contrast to the Gull Island populations which are expanding (Fig. 3). Ongoing APEX work has shown a significant relationship between breeding success and foraging effort for kittiwakes, but not for murres (Fig. 2). Both species show increased foraging effort with decreased prey availability, but

it appears that murres have a greater range of foraging effort within which they can still successfully produce chicks, as indicated by past studies (Burger and Piatt 1990). This raises the question: Is there a delayed or hidden cost to successful breeders that have had to "work harder" to raise their chicks? One way such a cost may be expressed is in decreased annual adult survival.

Measurement of survival:

Adult overwinter survival in seabirds has typically been measured by intensive banding and resighting programs (Harris and Wanless 1988; Aebischer and Coulson 1990; Hatchwell and Birkhead 1991; Hatch et al. 1993; Sydeman 1993). A suite of potential confounding factors (loss of bands, emigration, intracolony movement, observer failure to see marked birds) complicate survival estimates based on banding and resighting (Harris and Wanless 1988; Hatch et al. 1993). Models have been developed which account for some of these problems (Pollock et al. 1990); overcoming the remaining uncertainties depends directly on the amount of personnel effort that can be dedicated to banding and resighting work. Intensive effort will be required to resight banded birds, especially during the pre- egg-laying stage for kittiwakes (May) and murres (June). Adult common murres are particularly difficult to resight, due to the murre's compact body posture while at the nest site. Furthermore, precise survival estimates based on banding are ideally generated by multi-year studies, due to evidence that long-lived seabirds may sometimes skip one or more years of attempts at breeding (Hudson 1985; Golet et al. 1998).

Measurement of foraging effort:

Increased foraging effort may be the most important contributor to reduction in adult seabird survival (Golet et al. 1998), illustrating the trade-off between yearly reproductive output and longevity. The CISeaFFS study is currently measuring murre and kittiwake foraging effort (in terms of bird-hours spent away from the colony) using a series of four all-day nest (n= 8-12) watches, spread throughout the chick-rearing stage. All-day watches give information on nest-site attendance, foraging trip duration, and chick provisioning rate. However, this method requires intense personnel effort, making an increase in coverage not feasible. To elucidate the potential correspondence between foraging effort and adult survival demands larger sample sizes. We plan to use a Data Collection Computer (DCC) at both colonies to measure murre and kittiwake attendance throughout the breeding season. The DCC will give continuous 24-hour measurement of colony attendance throughout the breeding season, allowing for more powerful comparison of breeding effort and overwinter survival. An additional advantage of using the telemetry/DCC method to quantify foraging stress is the minimal effort required by field personnel once birds are radio-tagged. With equal personnel effot, the DCC generates far more comprehensive attendance data compared to visual observations. Pilot work done for this project in FY97 demonstrated the feasibility of this method. Foraging data obtained concurrently with APEX forage fish abundance and distribution data will give insight into the mechanisms that reduce or influence adult survival as well as productivity, elucidating the forces that drive population fluctuations.

## B. Methods

*Survival Component:* Resighting efforts to search for birds banded during the FY97 pilot work will commence in late May and early June 1998. Initial effort will focus on nest-sites at which birds were banded the previous year. Search coverage will then be expanded to include all visible nests, in order to document any intracolony movement. Coverage will also include roosting rocks and other gathering areas, to look for birds that may skip breeding in the year following banding, but continue to attend the colony.

To increase the population of individually marked birds, we plan to expand the banding work commenced in the FY97 pilot study. Breeding birds will be noosed, and their position in the colony will be noted on archival plot photos or sketches. Captured birds be individually banded as per USFWS protocol. All birds will be weighed using a spring balance, and culmen, head-bill, tarsus, and wing length (flattened, straightened, to longest primary) will be measured

*Sample Size and Survival Statistics:* Assuming a binomial distribution (sample unit being an individual murre, with survival being a yes or no), a power analysis of sample size in a two by two table (Steel and Torrie, 1980) predicts that a sample size of 47 marked birds per island would resolve a 6% difference in survival between colonies with acceptable statistical power and confidence (Table 1). To double the resolution (3%) would require a sample size nearly five times greater. A sample size of 125 is predicted to resolve a 5% difference with strong power and significance at the 0.05 level. Previous studies have reported murre survival rates ranging from 87% to 98%, measured at stable colonies (Hudson 1985, Sydeman 1993). Given that our study colonies represent relative extremes of population expansion and decline, it is not unreasonable to expect their survival rates to also be at the extreme ends of the normal range. Therefore, detection of a 5% difference with statistical significance should adequately address our primary hypothesis. To allow calculation of resighting probabilities, potentially obviating the use of Jolly-Seber or related models, our goal will be to have a minimum of 200 individually marked birds of each species at each colony.

*Foraging Component:* We will use radio transmitters to collect data on murre foraging effort (Uttley et al. 1984; Monaghan et al. 1994). As early in the breeding season as feasible, radios will be attached to murres and kittiwakes (n=15 per species per colony) following proven protocols using zip-ties, glue, and waterproof tape (D. Irons, USFWS, pers. comm.; M. Harris, Institute of Terrestrial Ecology, United Kingdom, pers. comm. Data Collection Computers (DCCs) will be used to remotely gather continuous 24-hour data on murre colony attendance throughout the breeding season. Instrumented and control murres will be visually monitored on selected days throughout the breeding season, to assess the impact of transmitter attachment on breeding and foraging performance (Wilson et al. 1986; Wanless et al. 1988; Wanless et al. 1989; Croll et al. 1992). Visual monitoring will be carried out by cooperators in the CISeaFFS component of APEX. Technical telemetry guidance and advice on study design will be provided

by research collaborator Dr. David Irons in coordination with the kittiwake component of the APEX project.

### C. Cooperating Agencies, Contracts, and Other Agency Assistance

The proposed research will be conducted by a research student, under the PI's supervision. A Research Work Order will be used to provide funding for one MSc. student at a university yet to be determined. Personal Services contracts may be used for statistical consultation and programming assistance.

## SCHEDULE

### A. Measurable Project Tasks for FY 98

| | |
|---|---|
| Oct. 1-Jan. 31: | Evaluate results of pilot FY 97 work; refine study design |
| Jan. 15-24: | Attend Restoration Workshop |
| Feb. 1-April 15: | Arrange logistics (resighting, capture and banding, nest monitoring, etc.) |
| April 16-Sept. 10: | Conduct field work |
| Sept. 11-Sept. 30: | Begin data analysis |

### B. Project Milestones and Endpoints

| | |
|---|---|
| April 15: | Resighting, banding, and nest monitoring protocols will be finalized |
| Sept. 10: | Field work designed to address all project objectives (listed under PROJECT DESIGN, Part A above) will be completed |
| Dec. 31, FY 99: | Preliminary data analysis will be completed |
| April 14, FY 99: | Project design modifications (based on FY 98 results) will be completed |
| April 15, FY 99: | Submit annual report (FY 98 findings) |
| Sept. 10, FY 99: | Field work, as necessary based on FY 98 results, will be completed |
| April 15, FY 00: | Submit annual report (FY 99 findings) |
| Sept. 30, FY 00: | Preparation of research results for publication in peer-reviewed journals will be completed |

### C. Completion Date

Our proposed research takes advantage of a natural comparative system (failing vs. thriving colonies) to reduce the time required to test the hypothesis that increased foraging effort will decrease adult survival. We propose two field seasons (FY98 and FY99) to ensure an adequate sample size and to allow for modification of project design based on initial results. The project will be completed by the end of FY 00, which is planned as a close-out year during which no new

research will be undertaken. Efforts in FY 00 will focus on the graduate student's thesis completion and defense, and on publication of research results in peer-reviewed journals.

## PUBLICATIONS AND REPORTS

The first planned product of the proposed research will be the annual report detailing FY 98 findings, due on April 15, 1999. Publication of project results in peer-reviewed journals will be pursued as soon as scientifically appropriate and logistically possible.

## PROFESSIONAL CONFERENCES

Results of this project will be presented at the Annual Meeting of the Pacific Seabird Group, and at local professional meetings where appropriate.

## NORMAL AGENCY MANAGEMENT

This research would not be conducted as a normal part of USGS research on seabirds.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The proposed research issues are related to management and conservation of seabirds in Alaska as addressed by the U.S. Fish and Wildlife Service (USFWS) 'Seabird Management Plan' (USFWS Region 7, Migratory Bird Management). The proposed work will complement and be coordinated with: i) long-term studies conducted by the Alaska Maritime National Wildlife Refuge (AMNWR, USFWS Region 7), which includes annual monitoring of seabird productivity at 9 major seabird colonies throughout Alaska; ii) related studies (APEX) of seabird-forage fish interactions being supported by EVOSTC in Prince William Sound; iii) EVOSTC-funded research on the Pacific sand lance; iv) ongoing studies of seabird populations in areas of oil and gas development conducted by the Minerals Management Service (MMS) in Alaska and the Biological Resources Division of the USGS and, v) ongoing studies of marine fish and oceanography conducted by the University of Alaska, Fairbanks out of the Kasitsna Bay Marine Lab in Kachemak Bay.

Logistic support from the USFWS and AMNWR will include vessel use, storage facilities, laboratory space, computer usage, and communications. Field sites and research platforms will be shared with the EVOSTC-funded APEX and sand lance projects. Telemetry equipment will be borrowed where possible, saving a minimum of $15K in the first year of funding for the proposed research.

**PRINCIPAL INVESTIGATOR**

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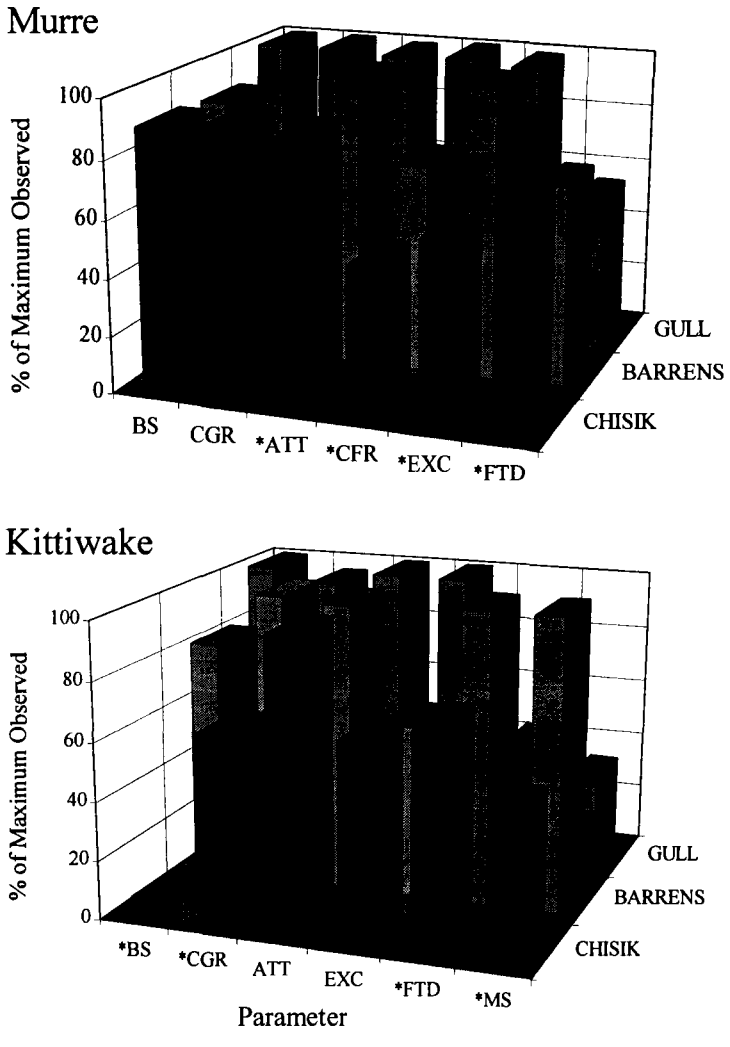
Table 1. Power analysis of sample size (in a two by two table). One minus beta is power; a power of <0.50 is typical in survival estimations. One minus alpha is the confidence interval. Ps and Pe are estimated survival fractions at two hypothetical colonies. Thus, with a sample size of 47 (transmitters per colony), we would expect to resolve a 6% difference (Ps minus Pe) with a power of 0.51 and 90% confidence intervals. With a sample size of 125, we would expect to resolve a 5% difference with a power of 0.75 and 95% confidence intervals. In general, as sample size doubles, variance is halved (Heisey and Fuller, 1985). Resolution of differences <5% demands unacceptably large sample sizes.

| alpha | Zalpha | beta | Zbeta | Ps | Pe | n = |
|---|---|---|---|---|---|---|
| 0.10 | 1.18 | 0.25 | 0.68 | 0.92 | 0.89 | 352.32 |
| 0.10 | 1.18 | 0.49 | 0.01 | 0.92 | 0.89 | 226.01 |
| 0.05 | 1.65 | 0.25 | 0.68 | 0.95 | 0.90 | 125.25 |
| 0.10 | 1.18 | 0.25 | 0.68 | 0.95 | 0.90 | 100.14 |
| 0.10 | 1.18 | 0.49 | 0.01 | 0.94 | 0.89 | 72.49 |
| 0.10 | 1.18 | 0.49 | 0.01 | 0.95 | 0.89 | 46.97 |


Figure 1. Study area in lower Cook Inlet. Colonies proposed for study of adult survival are located on Chisik and Gull Islands.




Parameters: BS- Breeding Success, CGR- Chick Growth Rate, ATT- Attendance by Adults, CFR- Chick Feeding rate, EXC- Exchange Rate of Brooding Adults, FTD- Foraging Time Duration, MS- Mean Meal Size. Asterisk (*) indicates significant difference in parameter values between colonies.

Figure 2. Variation in reproductive and behavioral parameters of seabirds at Chisik, Gull, and Barren Island colonies in 1996. Note high and similar breeding success of murres at Gull and Chisik, hypothetically made possible by increased foraging effort of Chisik murres. Chisik kittiwakes were apparently unable to compensate, and therefore failed to produce chicks.

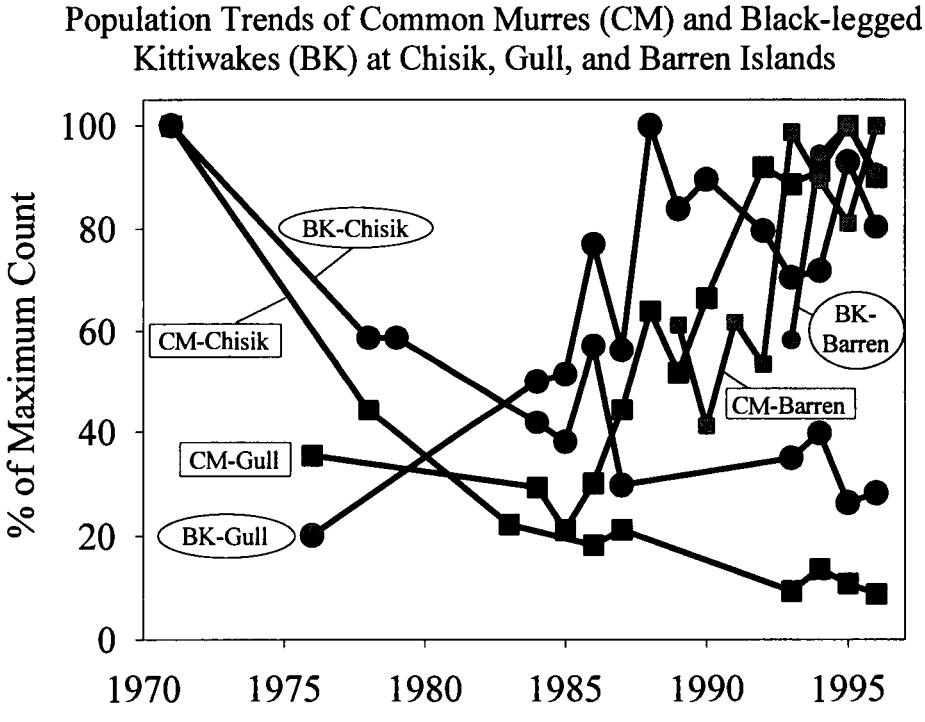



Figure 3. Population trends of murres and kittiwakes showing declines at Chisik Island and increases at Gull Island.

Revised 9/97
Approved TC 12-18-97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $10.6 |
| Travel | | $1.2 |
| Contractual | | $36.2 |
| Commodities | | $3.7 |
| Equipment | | $0.4 |
| Subtotal | $0.0 | $52.1 |
| General Administration | | $4.1 |
| Project Total | $0.0 | $56.2 |
| Full-time Equivalents (FTE) | | 0.4 |

| LONG RANGE FUNDING REQUIREMENTS | | | | |
|---|---|---|---|---|
| Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| $57.9 | $45.0 | $0.0 | | |

Dollar amounts are shown in thousands of dollars.

| Other Resources | | | | | | | | |
|---|---|---|---|---|---|---|---|---|

Comments:

**1998**

Prepared: 1 of 4

Project Number: 98338
Project Title: Survival of Adult Murres and Kittiwakes in Relation to Forage Fish Abundance
Agency: U.S. Geological Survey

FORM 3A
TRUSTEE
AGENCY
SUMMARY

12/9/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Personnel Costs:** | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 1998 |
| Vacant | Biotech | GS-5 | 2.5 | 2.1 | | 5.3 |
| Vacant | Biotech | GS-5 | 2.5 | 2.1 | | 5.3 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 5.0 | 4.2 | 0.0 | |
| | | | | | **Personnel Total** | $10.6 |

| **Travel Costs:** | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| Anc/Hom/Anc | 0.2 | 6 | 0 | 0.0 | 1.2 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $1.2 |

**1998**

Prepared: 2 of 4

Project Number: 98338
Project Title: Survival of Adult Murres and Kittiwakes in Relation to Forage Fish Abundance
Agency: U.S. Geological Survey

FORM 3B
Personnel
& Travel
DETAIL

12/9/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Air Charter Homer-Chisik (RT) (6 x $500/trip) | 3.0 |
| Boat Charter (Camp support; 2 RT Homer/Chisik @ 1500/trip) | 3.0 |
| Safety training | 0.2 |
| Research Work Order with University (to be determined) | |
| RWO Includes: | |
| Grad Student Stipend and Tuition | 28.0 |
| Benefits | 2.0 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $36.2 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Fuel (resighting from water, 15d @ 20gal/day @ 3.00/gal) | 1.0 |
| Misc. Equip. | 1.0 |
| Color bands (300 per species, per island) | 1.2 |
| Metal bands (300 per species, per island) | 0.5 |
| **Commodities Total** | $3.7 |

**1998**

Prepared:

Project Number: 98338
Project Title: Survival of Adult Murres and Kittiwakes in Relation to Forage Fish Abundance
Agency: U.S. Geological Survey

FORM 3B
Contractual & Commodities DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 1998 |
| Pelican case | 2 | 0.2 | 0.4 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | **New Equipment Total** | | $0.4 |

| **Existing Equipment Usage:** | Number | Inventory |
|---|---|---|
| Description | of Units | Agency |
| Data Collection Computer (ie, telemetry receiver and control unit; 2 @ 5k each) | 2 | FWS |
| Receiver and Antennae (2 @ 2K each) | 2 | USGS |
| Boston Whaler (camp and personnel support; @ 75K) | 1 | FWS |
| Laptop Computer (@1.5K) | 1 | USGS |
| Zodiac inflatables (required for resighting BLKI from water; 2 @ 7K each) | 2 | USGS |

**1998**

Project Number: 98338
Project Title: Survival of Adult Murres and Kittiwakes in Relation to Forage Fish Abundance
Agency: U.S. Geological Survey

FORM 3B
Equipment
DETAIL

Prepared: 4 of 4

12/9/97

Revised 6-24-97
Approved TC 12-18-97

# Prince William Sound Human Use and Wildlife Disturbance Model

| | |
|---|---|
| Project Number: | 98339 |
| Restoration Category: | General Restoration |
| Proposer: | K. Murphy, L. Suring/USFS |
| Lead Trustee Agency: | USFS |
| Cooperating Agencies: | ADNR |
| Alaska SeaLife Center: | No |
| New or Continued: | New |
| Duration: | 1st yr.<br>2 yr. project |
| Cost FY 98: | $139.2 |
| Cost FY 99: | $53.1 |
| Cost FY 2000: | $0.0 |
| Cost FY 01: | $0.0 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Western Prince William Sound |
| Injured Resource/Service: | Harbor seal, pigeon guillemot, cutthroat trout |


## ABSTRACT

This project will use geographic information system (GIS) techniques to describe current human-use patterns in western Prince William Sound and to model potential changes in those use patterns as a result of additional development (e.g., increased access). GIS-generated maps of present and projected human-use patterns will be incorporated with GIS maps of the distribution of resources injured as a result of the oil spill. This will provide a basis to identify areas where there may be existing and potential conflicts between human use and wildlife concentrations resulting in disturbance. Disturbance of injured wildlife may result in decreased productivity exacerbating the effects of the oil spill and prolonging the time to recover.

## INTRODUCTION

The Prince William Sound (PWS) ecosystem has experienced many changes in the last decade. The most notable of these are related to the Exxon Valdez oil spill (EVOS) of 1989. The EVOS caused direct and indirect effects on many resources throughout the oil spill area (EVOS Restoration Plan). Some of the oil spill effects have resulted in changes in human use patterns in PWS and other areas. For example, subsistence harvest patterns changed after EVOS (Seitz and Fall 1995), and commercial harvest of herring was closed in PWS for several years due to pathological problems believed to be caused by the spill. Land acquisition through the EVOS restoration program has made more land available for public use and habitat protection.

In addition to changes which are directly linked to EVOS, other changes in human use of PWS are occurring. Tourism patterns in PWS have changed as cruise ships altered their routes and new glacier tour cruises have been added. While the extensive commercial salmon fishery is expected to remain at about the same level, recreational boating and kayaking has increased dramatically in the last decade and is expected to continue to increase (ADOT 1995). Development in Chenega Bay and Tatitlek have made these communities more accessible. Additional changes in human use are expected as projects such as the Whittier access road or the proposed Bering River road are completed. The Whittier access road will make western PWS much more accessible to Alaska's largest population base. This improved access is expected to result in increased human use in PWS (ADOT 1995) and anticipated ecotourism development by Chenega Corp. will allow for greater dispersion of traffic throughout western PWS.

The State of Alaska Department of Transportation (ADOT) predicted increases in recreation and tourism boat traffic in PWS due to the installation of the Whittier access road (ADOT 1995). Using a baseline of 662 boats/day in 1994, ADOT predicted recreation and tourism boat traffic to increase to 1,621-2,408 boats/day by the year 2015. The majority of this increase is expected to occur in western PWS where a 600% or greater increase in recreation and tourism boat traffic is predicted. According to their analysis, this translates into an increase from 1-2 boats for every 4.8 km of shoreline to 1 boat for every 0.5-0.8 km of shoreline for areas closest to Whittier (i.e. Culross Island to Whittier). The ADOT analysis showed the greatest increase will occur in recreational sport fishing activities, but increases in hunting and hiking are also expected. With angler days predicted to increase from an average of 9,800 days to 81,750 days in the year 2015 the greatest potential for direct impact is likely to occur on fishery resources (ADOT 1995). Harvested wildlife species such as black-tailed deer and black bear will also be affected. Use is predicted to diminish with distance from Whittier, unless additional fueling stations are made available in PWS.

Increased human activity in PWS may affect the recovery of species injured by EVOS. Human-caused disturbance has been shown to have negative effects on a wide variety of species (e.g. York 1994; Boyle and Samson 1983). Some types of boat-based disturbance have been shown to reduce productivity in many species of birds (e.g. Sowls and Bartonek 1974) and in some seal species (e.g. Pitcher 1998). The potential effect of human disturbance varies with species, frequency and type of disturbance, season, and other factors (Knight and Cole 1991). As human use increases in PWS the potential for disturbance-related effects on resources also increases.

Human disturbance to marine mammals, seabirds, and shorebirds often occurs as people approach for viewing or photos or when beach activities such as camping and hiking disturb nesting birds.

Managing human use in large geographic areas is often very complex; management of PWS is the responsibility of numerous State and Federal Agencies, and private land owners. Presently, there is no single source of information on human use in PWS. This may create difficulties in resource management if human use increases as predicted and populations of injured resources are affected by human disturbance.

This project provides a foundation for displaying and understanding existing and future human use patterns in PWS, the potential disturbances on injured resources, and would make recommendations for management actions to minimize adverse effects of increased human use on injured resources. This proposal describes a pilot project which would focus on western PWS in FY98. If results provide meaningful information to the restoration program and to land managers, the project may be expanded to include all of PWS in future years. The project consists of three components:

1. Develop and evaluate a spatial computer model of existing human use patterns in PWS,
2. Use the model to project changes in human use patterns as a result of development and management actions in western PWS, and
3. Recommend management actions for public lands, and identify research needed to minimize potential future disturbance on injured resources.

The final product of this pilot project would be a report with management recommendations for State and Federal agencies and a geographic computer database. The report and computer model would be available to all agencies and to Chenega Bay to assist land owners and managers to better understand the potential human use of an area and make appropriate management decisions. While the project would generally take a broad-spectrum approach in describing potential disturbance patterns on injured resources and on subsistence species, we also propose a more in-depth analysis of three injured species: harbor seal, pigeon guillemot and cutthroat trout.

This project would provide a useful tool in many aspects of the EVOS restoration program. The model would help in the identification of appropriate research and monitoring sites to understand the effects of human disturbance on specific injured resources or services. It would help in identifying areas where subsistence harvests may be affected by increased recreation and other uses. In addition to benefitting restoration activities, the model and recommendations would benefit State and Federal agencies, and the Chenega Corporation, in land management planning and in the protection of resources.

## NEED FOR PROJECT

### A. Statement of Problem

Human activity in PWS is expected to increase significantly in the next decade (ADOT 1995). This project provides a management tool that would increase the effectiveness of management of resources and human use in PWS. The project has direct application under Habitat Protection and General Restoration as described in the EVOS restoration plan (EVOS Trustee Council 1994), and has the potential to aid in the restoration of most of the identified injured resources and services. The pilot phase of this project places emphasis on describing potential disturbance effects and developing management recommendations for harbor seals, pigeon guillemots and cutthroat trout on public lands in PWS.

**B. Rationale/Link to Restoration**

The Trustee Council has made significant progress in understanding the effects of the EVOS and in restoring and protecting the resources and services injured by the spill. However, the recovery of these resources and services may be affected by a dramatic increase in human use in PWS. The ADOT has predicted that the Whittier access road will result in an increase of over 600% in recreational and tourism boat traffic in parts of western PWS by the year 2015 (ADOT 1995). However, the Whittier road is one of several changes that will affect human use in PWS. For example, in the last 5 years new glacier cruise tours have been established in Whittier, more State and Federal lands have been acquired in western PWS, and the number of recreational boaters in western PWS has increased. As more people recreate and work in PWS, there will be higher levels of interactions between people and injured resources. Research has shown that human disturbance can cause a wide range of problems for wildlife and fish populations. At its most severe levels, disturbance can cause mortality or reduced productivity (Knight and Cole 1991). As human use increases in PWS, the potential for problems related to human disturbance to delay recovery of injured species also increases. By identifying existing and potential human use patterns in western PWS, the Trustee Council would be providing a tool that would assist in habitat protection, general restoration, and would also provide valuable information for research and monitoring projects.

This pilot project would take a broad-spectrum approach in describing potential disturbance patterns on injured resources and on subsistence species. We also propose a more in-depth analysis associated with three injured species: harbor seal, pigeon guillemot and cutthroat trout. This analysis would compare known distribution patterns of these species with the predicted disturbance patterns to provide more specific management recommendations. Harbor seals were selected because their haulout sites are often approached by tourism and recreational boats. Pitcher (1988) provides a summary of effects of disturbance at haulout sites; such disturbance can result in site abandonment, shifts to nighttime haulout schedules, or injury and increased pup mortality. Pigeon guillemots are susceptible to human disturbance during nesting because they nest on or near beaches that may also provide good campsites and fishing areas for people. Of sportfish species, cutthroat trout may be at the greatest risk. PWS is the northern-most extent of the range for this species. Populations in western PWS are generally small and poorly understood. Increased harvest of this species could further reduce the population (Gillikin, D. pers. com.).

### C. Location

The proposed pilot project would focus on western PWS; however, the project may be expanded to include the rest of PWS in future years. The project would benefit all State and Federal agencies with management responsibilities in PWS. The project would also benefit other land owners, especially the Chenega Corporation and the community of Chenega Bay.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Involvement from the community of Chenega Bay and from the Chenega Corporation is an important component of this project. In order to fully understand human-use patterns in western PWS, the human use patterns to and from Chenega Bay must also be incorporated into the model. The Chenega Corporation has agreed to cooperate on this project by supplying information on historical and current use patterns, and to comment on the predicted human use patterns identified by the model. Residents of Chenega Bay would be asked to participate in identifying activity patterns near the village and in southwestern PWS.

## PROJECT DESIGN

### A. Objectives

There are three objectives associated with this pilot project:

1. Describe existing and potential human-use patterns in western PWS

2. Identify areas where human disturbance has a high potential to affect injured resources.

3. Develop management recommendations for public agencies to minimize or eliminate the effects of disturbance on injured resources.

### B. Methods

Model Construction

Only water-based transportation will be considered in the description of human-use patterns in PWS. Vessel classes will be established to more accurately describe use patterns. Classes will be based primarily on size and function (e.g., personal pleasure craft, charter, tour, commercial fishing). Current number, locations, and trips of vessels by class in western PWS will be determined through registration records, fuel records, and harbor master information on slip rental, moorage and launches. Additional information will be provided through a user survey.

The extent of human use in western PWS will be described through an analysis of accessibility of the area by water craft in association with preferred destinations (e.g., recreational and commercial fishing areas, mooring buoys, camping sites, recreation cabins). Accessibility will

be defined as a function of the travel range of each vessel class. Average travel ranges will be assigned to vessel classes based primarily on fuel capacity. "Preferred" destinations will be described from existing information such as recreation sites maintained by land management agencies (e.g., U.S. Forest Service, Alaska Department of Natural Resources), commercial fishing areas (e.g., Alaska Department of Fish and Game, Prince William Sound Aquaculture Association), sport fishing areas (e.g., Alaska Department of Fish and Game), tour destinations (e.g., tour operators associations). Potential use levels of these sites will be determined from existing survey information collected at the Whittier harbor (USDA Forest Service, unpublished data) and from a mail survey of the patrons of the Whittier harbor. The survey will be distributed to individuals and groups known to work and recreate in PWS. This survey will help to refine model parameters on frequency and duration of trips associated with different vessel classes.

Cell-based modeling using the GRID feature of the ARC/INFO geographic information system (GIS) will form the basis of our approach to evaluate human-use patterns in western PWS (Environmental Systems Research Institute, Inc. 1994). Weighted distance functions will be used to describe areas that are available to and may be used by vessel operators. Separate grids of the water portion of western PWS will be created for the analysis of dispersion of vessels in each class. For each vessel class a source grid will be created which will represent trip initiation points (e.g., marinas, launch sites). The PATHDISTANCE function will be used to determine the minimum accumulative-travel cost from the source to each cell location on the grid. This function allows for the control of factors that influence dispersion. First source cells will be identified. Then the cost to travel to each neighbor that adjoins a source cell will be determined. Next, each of the neighbor cells will be ordered from least costly to most costly. The cell location with the least cost will be removed. Finally, the least-accumulative cost to each of the neighbors of the cell just removed will be determined. This process will be repeated until all cells on the grid have been assigned an accumulative cost.

Corresponding cost grids will also be established for each vessel class. A cost grid will assign an impedance value to each cell that depicts the cost involved in moving through any particular cell. The value of each cell in the cost grid will represent the cost-per-unit distance of passing through the cell, where a unit distance corresponds to the cell width (Environmental Systems Research Institute, Inc. 1994:253). Each cell location will be given a weight proportional to the relative cost incurred by a vessel passing through a cell. The cost units will be established on a relative scale of energy units expended. Variations of the horizontal and vertical factor features of the PATHDISTANCE function will be used in the cost grids to represent attraction zones associated with preferred destinations (e.g., recreational and commercial fishing areas, mooring buoys, camping sites, recreation cabins).

ARC/INFO GRID functions will be used to create additional grids in which each cell is assigned the accumulative cost to the nearest source cell. Additional functions will be used to combine the accumulative cost grids and the attraction zone grids to develop grids that represent dispersion of water craft by vessel class in western PWS. These dispersion grids will be combined through map algebra to describe areas of western PWS by use class (e.g., low, medium, high vessel densities). The dispersion and density grids will be combined with grids of sensitive areas for injured species to identify those areas where conflict may occur.

Model Evaluation

The model will provide predictions of movements and concentrations of water-vessels in the pilot study area. This information will be used to characterize areas of western PWS as having high, medium, and low densities of vessels by vessel class and total vessels on a monthly basis. Separate runs of the model will be made for each month from May through September. Actual vessel densities in representative areas will be determined, by month, through field surveys.

Three areas of western PWS within each of the high, medium, and low density classes (as predicted by the model) will be randomly selected. Counts of vessels present in each of the sample areas will be made each month from May through September during high-use (e.g., weekends) and low-use (e.g., mid-week) periods. Counts will be conducted from fixed-wing aircraft along line transects using the approach described by Anderson et al. (1979) and applied by Gasaway et al. (1986). Transects will be located 0.4 km apart and will traverse the sample areas. All vessels observed from transects during flights within the sample areas will be recorded by vessel class. Most vessels within sample areas are anticipated to have high sightability. However, small, nonmotorized vessels (e.g., kayaks) may not be obvious to the observers, especially if they are near the shoreline. A Sightability Correction Factor will be calculated for all vessel classes by conducting one intensive survey (e.g., following shorelines) each month in each density class while a standard survey is being conducted. The Sightability Correction Factors will be applied to the results of all transect surveys to provide an estimate of total number of vessels, by class, in the sample areas. The survey technique may be modified as experience in its application is gained.

Results of the field surveys will be used to determine if ranges of actual vessel densities in the sample areas correspond to the vessel density classes predicted by the model under current conditions. If model predictions are not corroborated by the results of the field counts, model parameters will be examined and modified to bring the model into compliance with field counts.

Model Application

Upon completion of the evaluation, the model will be used to estimate future use of western PWS under potential management changes (e.g., improved Whittier access, additional fuel sources provided). Analyses will be completed which will incorporate projections of increased use of western PWS to demonstrate expected temporal and spatial changes in use patterns. ARC/INFO grids of potential human-use patterns will be combined with existing GIS maps of the distribution and areas of essential habitat for injured wildlife and fish resources. Areas of potential conflict (e.g., high density human-use areas coinciding with essential habitat) will be identified.

Recommendations for management actions designed to minimize or eliminate potential conflict on public lands will be developed for all injured wildlife and fish resources based on information available in the published literature. More specific management recommendations will be developed to reduce potential risk to harbor seals, pigeon guillemot, and cutthroat trout. These recommendations will incorporate published literature and site-specific information available from ongoing studies in PWS.

### C. Cooperating Agencies, Contracts, and Other Agency Assistance

Forest Service personnel will be responsible for the development and evaluation of the human use dispersion model and its attributes. Evaluation of the model will be based on the results of aerial surveys. The Forest Service will conduct the literature search on human disturbance effects on injured resources, and develop management recommendations in cooperation with the State. Forest Service personnel will incorporate the model with known information for three injured species. Coordination with other agencies will be the responsibility of the Forest Service.

The State of Alaska, Department of Natural Resources (ADNR) is a partner on this project. The Chugach National Forest, ADNR, and Chenega Corporation are responsible for most land management within the study area. An ADNR Natural Resources Manager will provide input and coordination with the Division of State Parks and Outdoor Recreation, and the Division of Lands. This partnership would ensure that relevant State activities are included in the model, and that the management recommendations are compatible with State management responsibilities. ADNR will also provide information on other activities related to State management. These will include, but are not limited to, human use patterns related to the State Marine Parks, Alaska Marine Highway System, and commercial fishing industry. The State will also conduct the user survey, and incorporate results of previous surveys, to refine the information about existing use patterns.

Contracts for this proposal include airplane costs associated with conducting the aerial surveys. Chenega Corporation will collaborate on this project by working with the principal investigators to ensure that the human use model accurately displays existing activities on Corporation lands and activities associated with the community of Chenega Bay.

## SCHEDULE

### A. Measurable Project Tasks for FY98

| | |
|---|---|
| Oct. 1 - April 30: | Model development and literature review |
| Nov. 1 - 30: | Coordinate with Chenega Corporation |
| Jan. 15-24: | Attend annual restoration workshop (3 days) |
| May 1 - Sept. 30: | Conduct aerial surveys and user surveys |
| June 1 - Aug. 30: | Preliminary test of model based on initial aerial survey results |
| Sept. 15 - Sept. 30: | Begin analysis of survey results and evaluation of model |

### B. Project Milestones and Endpoints

All three of the objectives described in this proposal will be fully completed at the end of the pilot project in April 1999. Project milestones are described in the following schedule.

FY98

| | |
|---|---|
| Oct. 1 - April 30: | Model development, Literature search |

| | |
|---|---|
| May 1 - Sept. 30: | Conduct aerial surveys and user surveys |
| FY99 | |
| Oct. 1 - Dec 15: | Analyze survey data; evaluate, adjust and apply model with future projections of use |
| Jan. 1 - Feb. 28: | Develop management recommendations |
| March 1 - April 15: | Prepare final report and model |
| May: | Contract to have model prepared for distribution, if desired |

**C. Completion Date**

This pilot project will be completed by April 15th, 1999. This includes a final computer model and management recommendations. This does not include development of a user-based version of the dispersion model for direct use by land managers.

## PUBLICATIONS AND REPORTS

The first, and final, report for this project will be submitted in April 1999. There are no plans for publication during FY98; however, opportunities will be explored for FY99.

## PROFESSIONAL CONFERENCES

No conferences are anticipated for FY98; however, the principal investigators will request support to present the model at annual GIS and The Wildlife Society conferences in FY99.

## NORMAL AGENCY MANAGEMENT

This project is outside the scope of normal management for the Chugach National Forest. Development of human dispersion models similar to the proposed project has not been done previously in the context of National Forest management. The Forest Service has conducted public use surveys in 1992 and 1995 on the Chugach National Forest to provide information for the Forest Plan Revision process. Additional surveys are not planned for PWS. This project is also outside of normal agency management because of the combination of species being addressed. Populations of species injured by the EVOS are potentially some of the most vulnerable to disturbance associated with increased human use. Many of these species, such as harbor seals, rarely occur on National Forest land; however, activities and management associated with National Forest land can affect these marine species.

Ultimately, managing human use in PWS will be an interagency responsibility which will require coordination between multiple agencies. This project will provide useful information for all of these agencies.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Opportunity exists to integrate this project with many of the other restoration projects. During the development of this proposal, three of the principal investigators who work with harbor seals, pigeon guillemots and cutthroat trout were contacted. All three have agreed to cooperate with this project to facilitate the emphasis on management of these species. The primary principal investigator for the APEX project also identified opportunities to link the dispersion model to GIS data layers on forage fish densities, and seabird foraging and nesting areas. The combination of the dispersion model and the model developed through APEX would provide important insights into managing seabird populations.

The project would also be integrated into State and Federal agency management and would provide useful information to the Chenega Corporation and Chenega Bay in their ecotourism development plans for PWS. The Chugach National Forest will be continuing the revision of the 10 year Forest Plan during FY98. The information gathered for this project would be incorporated into the Forest planning process. Although the Forest Plan revision effort is anticipated to be completed before this project would be finalized, the principal investigators would work with the planning team to provide relevant information as it becomes available. The model and recommendations would also benefit biologists and recreation specialists who make project-level decisions for the Chugach National Forest. Many of these individuals would be involved in the development of this project and would have the opportunity to apply the information to other aspects of forest management. It is anticipated that other Federal agencies, such as National Marine Fisheries Service, would benefit from this project in their management activities.

The Alaska Department of Natural Resources is a partner on this project. This partnership will ensure that activities undertaken by State agencies are incorporated into the model and that the product would be beneficial to the State of Alaska.

## PROPOSED PRINCIPAL INVESTIGATORS

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(907) 783-3242
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Lowell H. Suring
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## PRINCIPAL INVESTIGATORS

Revision 7-97
Approved TC 12-18-97

# 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 | PROPOSED FY 1998 TRUSTEE AGENCIES TOTALS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | ADEC | ADF&G | ADNR | USFS | DOI | NOAA |
| Personnel | $0.0 | $78.5 | | | | | | |
| Travel | $0.0 | $1.2 | | | | | | |
| Contractual | $0.0 | $40.5 | | | | | | |
| Commodities | $0.0 | $1.9 | | | | | | |
| Equipment | $0.0 | $2.5 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | $0.0 | $124.6 | | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| General Administration | $0.0 | $14.6 | | | | | | |
| Project Total | $0.0 | $139.2 | | $53.1 | $0.0 | $0.0 | $0.0 | |
| Full-time Equivalents (FTE) | 0.0 | 1.4 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | $0.0 | $0.0 | | $0.0 | $0.0 | $0.0 | $0.0 | |

Comments:

**1998**

Project Number:98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Lead Agency: US Forest Service

FORM 2A
MULTI-TRUSTEE
AGENCY SUMMARY

Prepared:



7/8/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $63.5 |
| Travel | | $0.0 |
| Contractual | | $38.5 |
| Commodities | | $1.3 |
| Equipment | | $2.5 |
| Subtotal | $0.0 | $105.8 |
| General Administration | | $12.2 |
| Project Total | $0.0 | $118.0 |
| Full-time Equivalents (FTE) | | 1.1 |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 |
|---|---|---|---|
| $47.3 | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

1998

Project Number:98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Prepared:



7/8/97

## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 1998 |
| K.Murphy | Project Leader | GS-9 | 4.3 | 4.4 | | 18.9 |
| L.Suring | Wildlife Biologist | GS-12 | 4.0 | 6.0 | | 24.0 |
| D.Gillikin | Fish Biologist | GS-9 | 2.0 | 4.1 | | 8.2 |
| Seasonal | Bio Tech | GS-7 | 1.0 | 2.6 | | 2.6 |
| D.Hacket | Recreation Planner | GS-12 | 0.7 | 5.7 | | 4.0 |
| Karen Preston | GIS | GS-9 | 0.5 | 4.6 | | 2.3 |
| Seasonal | Bio Tech | GS-9 | 0.8 | 4.4 | | 3.5 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 13.3 | 31.8 | 0.0 | |
| | | | | | Personnel Total | $63.5 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | Travel Total | $0.0 |

**1998**

Prepared:



Project Number: 98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3B
Personnel
& Travel
DETAIL

7/8/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | | Proposed |
|---|---|---|
| Description | | FY 1998 |
| Air Charter | 4 hrs @ $250/hour | 1.0 |
| Contract with Chenega Corp for planning | | 5.0 |
| Air Survey contract | | 32.5 |
| When a non-trustee organization is used, the form 4A is required. | **Contractual Total** | $38.5 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Train Tickets | 0.1 |
| Training for GIS GRID | 1.2 |
| **Commodities Total** | $1.3 |

**1998**

Prepared:



Project Number: 98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3B
Contractual & Commodities DETAIL

7/8/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 1998 |
| Computer | | | |
| Soft ware | | | 1.5 |
| Misc supplies | | | 1.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $2.5 |

| **Existing Equipment Usage:** | Number | Inventory |
|---|---|---|
| Description | of Units | Agency |
| | | |

**1998**

Project Number: 98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3B
Equipment
DETAIL

Prepared: 7/8/97

## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | | $15.0 | | | | | | |
| Travel | | $1.2 | | | | | | |
| Contractual | | $2.0 | | | | | | |
| Commodities | | $0.6 | | | | | | |
| Equipment | | $0.0 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | $0.0 | $18.8 | | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| General Administration | | $2.4 | | | | | | |
| Project Total | $0.0 | $21.2 | | $5.8 | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.3 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

**1998**

Project Number: 98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Prepared:



7/8/97

## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 1998 |
| | Natural Resource Manager | 16 | 3.0 | 5.0 | | 15.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 3.0 | 5.0 | 0.0 | |
| | | | | | Personnel Total | $15.0 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| RT Anchorage to Cordova | 225.0 | 1 | 5 | 150.0 | 975.0 |
| Day trips to Whittier | | | 5 | 42.0 | 210.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | Travel Total | $1,185.0 |

1998

Prepared:



Project Number: 98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Personnel
& Travel
DETAIL

7/8/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| User Survey, printing, mail | 2.0 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $2.0 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Train tickets | 0.1 |
| Misc supplies | 0.5 |
| **Commodities Total** | $0.6 |

1998

Prepared:



Project Number: 98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Contractual & Commodities DETAIL

7/8/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| New Equipment Purchases: | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 1998 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

| Existing Equipment Usage: | Number | Inventory |
|---|---|---|
| Description | of Units | Agency |
| | | |

**1998**

Project Number: 98339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Equipment
DETAIL

Prepared:



7/8/97

Approved TC 8-6-97

# Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem

| | |
|---|---|
| Project Number: | 98340 |
| Restoration Category: | Monitoring |
| Proposer: | T. Weingartner/UAF |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | No |
| New or Continued: | New |
| Duration: | 1st yr.<br>4 yr. project |
| Cost FY 98: | $77.1 |
| Cost FY 99: | $85.8 |
| Cost FY 2000: | $53.7 |
| Cost FY 01: | $62.8 |
| Cost FY 02: | |
| Geographic Area: | Resurrection Bay/Gulf of Alaska shelf |
| Injured Resource/Service: | All |


## ABSTRACT

The 27-year time series of temperature and salinity data from hydrographic station GAK1 near Seward shows substantial interannual and interdecadal variability that could influence the Gulf of Alaska shelf ecosystem. This program will continue this time series and quantify the interannual and interdecadal variability of this shelf. A related goal is to resolve better the time and vertical structure of this variability at periods ranging from the tidal to the interannual. This information will aid in assessing progress in the recovery and restoration of organisms and services affected by the oil spill, and will aid in designing a long-term, cost-effective ecosystem monitoring program for this shelf.

## INTRODUCTION

This proposal describes a four-year program to maintain the existing 27-year time series of conductivity–temperature versus depth (CTD) data collected at hydrographic station GAK1 on the north central Gulf of Alaska shelf. We will continue this time series by monthly CTD sampling that will provide vertical profiles of temperature and salinity that extend from the surface to the bottom and with hourly sample of temperature and salinity collected by instruments at several fixed depths. These instruments will be mounted on a subsurface mooring that will be deployed year-round. Our goals are to: 1) maintain the GAK1 sampling so that the substantial interannual variability in temperature and salinity in the Gulf of Alaska can be documented, and 2) assist in building an inexpensive long-term, comprehensive monitoring program for this shelf. The GAK1 environmental data are representative of conditions in the northern Gulf of Alaska and the Bering Sea (Royer, 1993) and are being used to assess the role of environmental variability in the ecology of fisheries and marine mammals in these regions. Station GAK1 lies in 260 m of water at the mouth of Resurrection Bay, midway between Prince William Sound and Cook Inlet (Figure 1). GAK1 data should be helpful in placing many of the restoration studies sponsored by the Trustee Council in the context of interannual and interdecadal hydrographic variability. These data would also complement the goals of the Gulf of Alaska component of the U.S. Global Ocean Ecosystem Dynamics program (GLOBEC), scheduled to commence in 1998. GLOBEC is supported by the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA). It consists of three components: monitoring, process studies, and modeling. Monitoring will begin in the Gulf of Alaska in 1998, with modeling and process studies following in 2001. The proposal described here will encourage synthesis of the ecosystem studies supported by the Trustee Council and GLOBEC. In the following paragraphs we summarize the regional oceanography and the historical data from GAK1. This background information provides the context for understanding the rationale and the design of the project described in subsequent sections.

The circulation on the shelf and over the slope of the Gulf of Alaska is predominantly alongshore and cyclonic (counterclockwise) on average (Reed and Schumacher, 1986). Along the continental slope the flow consists of the Alaska Current, a relatively broad, diffuse current in the north and northeast gulf, which intensifies to become the swift and narrow western boundary current, the Alaskan Stream, in the west and northwest gulf (Figure 2). Together these currents comprise the poleward limb of the North Pacific Ocean's subarctic gyre and provide the oceanic connection between the Alaskan shelf and the Pacific Ocean.

The Alaska Coastal Current is the most striking shelf circulation feature in the gulf, and station GAK1 is positioned along its inshore edge. The main axis of this swift (0.2–1.8 m $s^{-1}$) westward-flowing current is within 35 km of the coast (Royer, 1981; Johnson et al., 1988; Stabeno et al., 1995). The coastal current is a perennial feature that circumscribes the Gulf of Alaska shelf for some 2500 km (at a minimum) from its origin on the northern British Columbia shelf (or possibly even the Columbia River depending on the season) to where it enters the Bering Sea in the western gulf. The current is intimately connected to Prince William Sound; feeding the sound through Hinchinbrook Entrance and draining it primarily through Montague Strait and the westernmost passes (Niebauer et al., 1994). It is also the source of shelf waters for Cook Inlet

and transports inlet waters southwestward through Shelikof Strait (Muench et al., 1981). The Alaska Coastal Current transported much of the oil spilled by the *Exxon Valdez* along the south and west coasts of Alaska (Royer et al., 1990).

The dynamics of the Gulf of Alaska shelf are closely coupled to the Aleutian Low atmospheric pressure system. Storms propagate eastward into the gulf and are blocked by the mountain ranges of Alaska and British Columbia. Consequently regional winds are strong and cyclonic and precipitation rates are very high. On the shelf, these winds impel an onshore surface Ekman drift and establish a cross-shore pressure gradient that forces the Alaska Coastal Current. The high rates of precipitation, up to 8 m $yr^{-1}$, cause an enormous freshwater flux (~20 % larger than the average Mississippi River discharge) that feeds the shelf as a "coastal line source" extending from Southeast Alaska to Kodiak Island (Royer, 1982). The seasonal variability in winds and freshwater discharge (Figure 2) is large. (Winds are represented in Figure 2 as the upwelling index, a measure of the strength of cyclonic wind stress in the gulf. Negative values mean coastal convergence and downwelling while positive values signify coastal divergence and upwelling. With respect to Alaska's south coast negative values imply winds blowing to the west and positive values imply that the winds blow to the east.) The mean monthly "upwelling index" at locations on the Gulf of Alaska shelf is negative in most months, indicating the prevalence of coastal convergence. Cyclonic winds are strongest from November through March and feeble or even weakly anticyclonic in summer when the Aleutian Low is displaced by the North Pacific High (Royer, 1975; Wilson and Overland, 1986). The seasonal runoff cycle (Figure 2) exhibits slightly different phasing from the winds: it is maximum in early fall, decreases rapidly through winter when precipitation is stored as snow, and attains a secondary maximum in spring due to snowmelt (Royer, 1982).

Shelf hydrography and circulation vary in response to the annual cycles of wind and runoff. Figure 3 contrasts the cross-shore salinity structure in April and September 1983. (Density gradients are important in ocean dynamics and salinity is the predominant influence on ocean density in the Gulf of Alaska.). In April, the stratification and the offshore front (defined here to be the surface intersection of the 32.0 isohaline) are relatively weak. By contrast, in September a 25 km wide wedge of strongly stratified water lies adjacent to the coast and is bounded on the offshore side by a prominent front. The swiftest alongshore flows are found within and inshore of the front (Johnson et al., 1988), and most of the total transport is associated with the baroclinic component (Stabeno et al., 1995). The latter result probably accounts for Royer's (1979) finding that monthly coastal sea level variations at Seward are in-phase with, and have nearly the same amplitude as, the upper ocean dynamic height at GAK1. (Dynamic height is a function of the vertically integrated ocean density. Horizontal gradients of dynamic height are proportional to the pressure gradients that accelerate ocean currents and provide an estimate of the oceanic transport.) His finding is remarkable given the different nature of the sampling techniques: the sea level records were sampled hourly and then averaged into monthly means whereas the dynamic heights were from hydrographic measurements at GAK1 occupied several months apart. He also found that sea-level and precipitation anomalies were well correlated.

Both of Royer's results suggest that there might be a relationship between monthly (and perhaps shorter period) *cross-shelf dynamic height (or upper ocean density) gradients* and winds and/or

freshwater discharge. Conceivably, the monthly anomalies of these variables are also correlated. If firm relationships among these parameters can be established, then the alongshelf (baroclinic) transport might be gauged from a conveniently located (e.g., GAK1) hydrographic station or mooring. Moreover, observations at a single location would probably reflect fluctuations in transport along vast portions of the shelf since variations in forcing (wind and runoff) are also coherent over a broad alongshore distance (Royer, 1982, Livingstone and Royer, 1980). Such a result would be enormously useful for model evaluation (and perhaps for data assimilation), retrospective studies, and monitoring.

It is very likely that transport variations in the Alaska Coastal Current affect the survival and/or condition of a number of marine organisms. This flow is apparently important in advecting zooplankton to important juvenile fish foraging areas. Napp et al. (1996) and Incze and Ainaire (1994) find that the major cohort of naupliar stage larvae available to first-feeding pollock larvae in Shelikof Strait originate in February–March on the shelf offshore of Prince William Sound and east of GAK1. Other studies indicate that the coastal current is an important feeding and migratory corridor for numerous species of marine mammals (Calkins, 1986) and seabirds (DeGange and Sanger, 1986).

Figure 3 also suggests that near-bottom salinities are higher in fall than in spring and this is the case on annual average. Xiong and Royer (1984) showed that maximum bottom salinities occur in fall and are nearly coincident with minimum surface salinities and maximum inshore stratification (Figure 4). Although surface waters are diluted by coastal discharge (which peaks in fall), the source of the high salinity water is the onshore intrusion of slope water (Figure 5) in response to the seasonal relaxation (or reversal) in downwelling (Royer, 1975; 1979). The deep water influx in summer from across the continental slope could be important in re-supplying nutrients to the Gulf of Alaska shelf and adjacent embayments and therefore, plays an important role in biological production.

The oceanographic description sketched above stems from research that began in 1970. Beginning that year research vessels from the University of Alaska and other organizations opportunistically sampled station GAK1 while in transit to and from the Seward Marine Center. This ad hoc sampling, conducted at nominally monthly intervals, was the beginning of what is now a 27-year time series for this station. Sampling became more routine (~monthly) in the past five years with support from NOAA and using a 25 foot vessel operated by the University of Alaska's Institute of Marine Science. As a result of these efforts the GAK1 data set comprises the longest ocean time series for the high-latitude North Pacific Ocean, and the only one that includes salinity (Royer, 1993). These data reveal substantial interannual and decadal scale variability in both temperature (Royer, 1993) and salinity (Royer, 1996).

For example, Royer (1993) showed pronounced interdecadal temperature variations that [illegible] colder water in the 1970s, followed by warmer conditions in the 1980s and a return to normal or cooling conditions in the 1990s. Coincidentally, the relative dominance of commercially important fish species changed in the mid-1970s; crab and shrimp declined while salmon and groundfish populations increased (Albers and Anderson, 1985; Blau, 1986; Hollowed et al., 1994; Thompson and Zenger, 1994; Francis and Hare, 1994). These population shifts coincided

with the beginning of a decadal North Pacific change in the atmosphere and ocean (Trenberth and Hurrell, 1994). Subsequent changes in this ecosystem followed in the 1980s with substantial declines in populations of sea lions (Merrick et al., 1987) and puffins (Hatch and Sanger, 1992).

Royer (1993) also showed that Sitka (Alaska) air temperature variability (for which records extend back to the mid-1800s) correlates with the GAK1 temperature anomalies at 200 and 250 m depths. He found that the 18.6 year lunar nodal tide accounts for a statistically significant fraction of the Sitka air temperature variability. Using the Sitka air temperatures as a proxy for shelf water temperatures, Parker et al. (1995) subsequently showed that the abundance of halibut and other commercially important species varies on a similar time scale and in conjunction with northern North Pacific Ocean temperatures. While these correlations do not imply causality, they underscore the possible significance of monitoring ocean climate to detect both periodic changes and more radical shifts in the marine environment.

There are also low-frequency variations in upper ocean salinities at what might be an 11–12 year period, which Royer (1996) ascribed to variations in runoff and precipitation. Much of the interannual variability in precipitation in the Gulf of Alaska is associated with changes in the strength and position of the Aleutian Low (Cayan and Peterson; 1989). Changes in upper ocean salinity could affect circulation in the Alaska Coastal Current and also influence biological production by varying frontal properties and the vertical stratification of the water column (Mann and Lazier, 1991). The GAK1 data also show substantial interannual variations in bottom water salinities, although these are not linearly correlated with variations in surface salinity. The absence of a correlation is not surprising because near-bottom salinities are linked to shelfbreak processes, while surface variations are associated with precipitation and runoff.

Salinities of deeper shelf water (depths > ~125 m) are likely correlated with nutrient concentrations at these depths. This potentially valuable relationship is suggested by Figure 6 showing the salinity–$NO_3$ relationship at stations within the Alaskan Stream and on the western shelf. The data come from the only synoptic deep ocean and shelf nutrient data available for the northern Gulf of Alaska, collected in May–June 1993, between 125 and 450 m depth during the WOCE (World Ocean Circulation Experiment) P17N section. This depth interval covers the range of bottom water salinities observed by Royer (1996) and Xiong and Royer (1984) and the correlation appears to be good. Note that a change in salinity from 32.0 to 33.0 involves a near doubling of the $NO_3$ concentration. Similarly tight relationships are apparent in plots of salinity versus phosphate and silicate. If salinity–macronutrient relationships can be statistically quantified for the shelf it might be possible to use the GAK1 salinity time series as a proxy for subsurface nutrient concentrations. This relationship could be exploited in retrospective studies and would aid in the design and maintenance of future monitoring programs because salinity can be accurately measured much more easily (and inexpensively) than nutrients.

In summary several data sets now suggest that the Gulf of Alaska ecosystem is sensitive to environmental variations on time scales ranging from interannual to interdecadal. Other data sets suggest possible biophysical linkages that cause these ecological responses. However, we lack an adequate characterization of shorter period (seasonal to synoptic) variations that might impinge on the biological components of this ecosystem. Moreover, a mechanistic understanding of the

physical dynamics of the Gulf of Alaska shelf and the processes linking environmental variability to ecosystem alterations is lacking. These are complex problems that require a concerted and interdisciplinary approach involving process-specific studies in addition to ecosystem monitoring. Some of these programs (APEX and SEA) are sponsored by the Trustee Council while a new initiative. the US Global Ocean Ecosystem Dynamics program will begin in 1998 on the Gulf of Alaska shelf. The GLOBEC program is specifically designed to elucidate details of the mechanisms underlying physical and biological environmental change on the shelf. For example, the nutrient cycles and concentrations on the Gulf of Alaska shelf are poorly understood at present (Reeburgh and Kipphut, 1986) but will be investigated in the GLOBEC program. Those results should benefit the monitoring proposed herein. In tandem, the GLOBEC and Trustees supported efforts will lead to improvements in ecosystem monitoring.

While the GAK1 time series has illuminated ocean variations having potentially significant ramifications for the marine ecosystem, the monthly sampling will not detect what might be important variations on shorter time scales. Present-day technology now allows inexpensive and accurate sampling at high temporal resolution of temperature and salinity from moorings deployed year round. In combination with monthly CTD sampling, this technology will enhance the value of the historical record. maintain the GAK1 time series, and contribute to the design of long-term ecosystem monitoring programs. The collection of these data form the basis of this proposal.

## NEED FOR THE PROJECT

### A. Statement of the Problem

The GAK1 monthly time series portrays the very large interannual and interdecadal variability of the high latitude North Pacific. With a greater sampling rate, shorter period variations can be detected, revealing any temporal aliasing problems. The results will enhance interpretations of the historical data and place the magnitude of previous anomalies in a better statistical framework. Moreover, the time series could serve as a proxy for transport in the Alaska Coastal Current. Variability in the marine environment, as reflected in ocean temperatures and salinities, and, if possible, shelf circulation, need to be quantified to understand the structure of, and changes in, the northern Gulf of Alaska marine ecosystem. Such changes might influence the recovery of many of the marine species and marine services listed in Table 4 of the Proposal Invitation. In conjunction with the historical data set from GAK1, the monitoring program described below will provide a useful data set to EVOS investigators and others concerned with ocean climate variations.

### B. Rationale/Link to Restoration

This monitoring proposal provides an information service to current and future investigators working in the Gulf of Alaska and adjacent waters who need information on environmental variability. The information will help assess recovery and restoration progress by allowing these issues to be analyzed within the context of the long-term variability of the physical environment.

The GAK1 data set provides some of that information and the proposed measurements will enable continuation of these efforts by collecting time series at GAK1 of:

1. Monthly temperature and salinity at every meter throughout the water column using a conductivity–temperature–depth (CTD) instrument, and
2. Hourly temperature and salinity at several fixed depths distributed throughout the water column.

This information will assist in:

1. Understanding thermohaline variability on time scales ranging from the tidal to the interdecadal,
2. Interpreting historical data sets for use in retrospective studies,
3. Configuring a cost-effective long-term monitoring program, and
4. Designing process studies necessary to develop ecosystem models for this shelf.

### C. Location

The field work will be conducted at Station GAK1 at the mouth of Resurrection Bay. Both the CTD work and the mooring deployment and recovery operations will be conducted from the Seward Marine Center using the 25 foot vessel, *Little Dipper*. All data collected as part of this program will be available to any who desire it via files on internet. The monthly CTD data will be combined with the existing historical data that are on the homepage, http://ims.alaska.edu:8000/gak1/gak.dat. A new homepage will be created for the hourly time series after mooring recovery and editing of the data. The homepages will be linked.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

We do not see any overt connection to traditional ecological knowledge. However, the most expedient way to share these data with both the public and scientific communities is via the internet. Such a link will allow easy access to the data for those working at the community level and with traditional ecological knowledge. The principal investigator is a member of the National Science Foundation's Partners in Science Program and is interested in sharing these data with the K–12 public school system. Again, this connection is primarily effected through the internet and broadens the public's ability to understand the marine environment and research. Through the Partners in Science Program, school children can explore marine science by accessing and using the data from GAK1. At this moment, the Partners program includes public schools (and home schoolers) in the Fairbanks, Grayling, Anchorage, and Juneau school districts. This data will form the basis of educational modules that explore ocean variability at time scales ranging from the interdecadal to the semi-diurnal. More importantly, student and teacher access to this data will allow them to explore it according to their own interests. Very likely these data will eventually contribute to displays at the Alaska SeaLife Center. We have had preliminary discussions with the Executive and Science Directors of the center regarding this matter.

## PROJECT DESIGN

### A. Objectives

There are two overarching objectives of this multi-year program. First, we want to continue the 27-year time series at station GAK1 through a combination of monthly CTD measurements and year-long deployments of a mooring containing temperature and conductivity (T/C) recorders. Second, we want to contribute to the design of a monitoring program for the Gulf of Alaska shelf. The optimal system is one that is cost-effective yet minimizes contamination associated with spatial and/or temporal aliasing in sampling. It is unclear if aliasing is a problem and neither sampling procedure alone can adequately address this issue. The CTD measurements provide high vertical resolution but, with monthly sampling, they could lead to temporal aliasing. In contrast, the T/C data provides high temporal resolution but could be spatially aliased because they are distributed over a limited number of depths. The sampling schemes complement one another and can resolve these problems. We recognize that our generic goal of ecosystem monitoring is a long-term undertaking requiring incremental efforts. This proposal is one essential step toward that goal and to guide our efforts we have formulated several project–specific objectives. These are:

1. Determine the within-month variance of temperature and salinity at a given depth. Such data are lacking and it is difficult to determine the significance of a single monthly measurement (as determined from the CTD data) relative to the variability observed within a given month. These basic statistics can be used to estimate the statistical significance of temperature or salinity anomalies observed in the past. This information will be placed on the GAK1 homepage so that users will have access to it as they use the historical data.
2. Determine the rate of change of water mass properties (temperature and salinity) and the phasing of these changes at different depths. Some of these features might be temporally aliased by monthly sampling. These changes need to be resolved to understand the dominant oceanic time scales and the relationship between low-frequency variations (monthly and longer) and shorter period fluctuations (synoptic scale events). The data files will be made available on the time series homepage for downloading and as a graphical display. Key events will be highlighted and discussed as part of the graphical display.
3. Determine how variance in temperature, salinity and dynamic height are distributed seasonally and over depth. Are there distinct vertical "modes" of variability that change with season? These results will also be summarized in a file containing textual, tabulated, and graphical information and will be accessible via the time series homepage.
4. If the temperature/conductivity recorders provide a useful estimate of dynamic height, then determine the joint effects on Seward sea-level of dynamic height and winds. Over what time-scales are these variables coherent with one another and with Seward sea-level? The results will be placed on the time series homepage.

The first three objectives will continue the historical data base and aid in monitoring design. The fourth objective is a feasibility study that will contribute to monitoring design.

## B. Methods

Funds are requested to monitor Gulf of Alaska temperature and salinity through FY 01, at which time a restructuring of the program described here will probably occur. By this time, the APEX and SEA programs will be completed and preliminary results from the U.S. GLOBEC sponsored Gulf of Alaska monitoring component will be available (US GLOBEC, 1996). Accomplishments from these programs (and from the work proposed herein) will catalyze a reconsideration of the monitoring effort. In addition, researchers working at the Alaska SeaLife Center will probably have monitoring interests to be considered as well.

We propose to collect data monthly with the Institute of Marine Science's 25' *Little Dipper* using a Seabird SBE-25 internally-recording CTD deployed from the vessel's winch. The sensors on this CTD are calibrated annually by the manufacturer. Field checks on the conductivity sensor are made from bottle salinities collected during each cast and analyzed on the salinometer at the Seward Marine Center. This procedure allows detection of CTD drift between calibrations by the manufacturer. The historical salinity data has an accuracy of ~0.01 or better using this instrument and these procedures. Temperatures are accurate to within 0.005°C.

The monthly sampling will be complemented by hourly measurements from six temperature/conductivity recorders (Seabird MicroCats; SBE model 37-SM) incorporated in a taut wire, subsurface mooring at GAK1. The mooring can be deployed and recovered by the *Little Dipper* during the CTD cruises. The instruments will make hourly measurements at nominal depths of 30, 60, 100, 150, 200, and 250 meters. This distribution covers the near-surface (30 m), the upper ocean (30–100 m), mid-depth (150–200 m) and bottom (200–250 m) of the water column. (Although observations at the surface would be useful, obtaining these would entail a mooring with substantially higher hardware and fabrication costs and the need for a larger vessel for servicing.) The MicroCat at 30 m depth includes a pressure sensor to measure mooring motion. (Strong currents can cause the mooring to lean with the flow, which results in instruments sampling at depths other than those desired. While we do not believe that this will be a severe problem at GAK1, the possibility needs to be assessed. Data from the uppermost instrument is most susceptible to contamination by mooring motion. The pressure data will identify suspect sections of the data record. These portions might be correctable using the monthly CTD data with the time record of instrument depth.)

Our prior experience with Seabird instruments similar to the MicroCats stems from nearly 25 year-long deployments in the Chukchi Sea. The maximum drift (and therefore uncertainty) in salinity over a one year period was ~0.05. More often salinity uncertainties were ~0.01, an order of magnitude smaller than anomalies reported by Royer (1996). Finally, the monthly CTD sampling will provide an additional check on MicroCat performance.

We request funds for the purchase of two sets of mooring equipment (MicroCats and acoustic releases) so that continual monitoring can be maintained while instruments are being serviced and/or calibrated annually. These procedures require that instruments be out of the water from 3–4 months. Therefore, reliance on a single set of equipment would mean that one-fourth to one-third of the annual cycle would not be acquired by the moored instruments. We envision

purchasing one mooring in FY 98 and a second in FY 99. Thereafter, only expendable parts would need to be purchased as the instruments will be recycled. This procedure will leave data gaps of only a few hours duration at most.

The analyses of the data sets are straightforward.

Objective 1 will be achieved using univariate statistics. The effective number of degrees of freedom, based on the integral time scales for the temperature and salinity time series, will be used to construct confidence limits. The integral time scales are determined from the autocorrelation function (e.g., Kundu et al., 1975) and provide insights on the temporal characteristics of these variables at each depth.

Objective 2 is largely concerned with temporal aliasing issues associated with monthly sampling. Among the important processes that might be aliased are the summer onshelf influx of dense bottom water, changes in upper ocean stratification throughout the year as a consequence of winds and runoff, and the response of the thermohaline structure of the water column to synoptic scale forcing by the wind.

Objective 3 will be achieved by examining the empirical orthogonal functions (EOFs) of the temperature and salinity time series. The EOFs decompose the system variance into a set of linearly independent functions with each describing a unique spatial and temporal structure. For the mooring data the system variance would be that computed from the salinity (or temperature) time series at all depths. Six EOF modes will result from the analysis because six depths are sampled. The modes are ordered by the proportion of the total system variance that each comprises; the first mode accounts for the greatest fraction of system variance and the sixth mode accounts for the smallest proportion. Often only a few modes are required to describe the system variance and the significance of a given mode will be assessed following Overland and Preisendorfer (1982). The spatial structure of a mode describes the distribution of amplitude with depth, while its temporal structure describes how the mode varies through time. The EOFs are useful in consolidating large and complicated data sets into smaller correlated subsets that facilitate physical interpretation. They might also contribute to future monitoring design by suggesting times and/or depths that are either over or under sampled. In the latter case, the EOFs could identify potential temporal or spatial aliasing problems.

Objective 4 will correlate winds and upper ocean density (dynamic height) with Seward sea-level. This motivation follows from Royer's (1979) observation of a statistically significant relationship between monthly dynamic height and Seward sea level. His findings suggest that a time series of sea-level and/or dynamic height at a single location might provide an index of transport variability in the Alaska Coastal Current. To firmly establish the relationship between coastal transport and sea-level will require making direct current measurements of the current and comparing these with sea level. While such measurements are beyond the scope of this proposal, detection of significant relationships would provide compelling support to undertake a more ambitious transport measurement program. We regard this last objective as a feasibility study that will relate sea-level fluctuations to the two dominant forcing mechanisms for the shelf circulation: freshwater (which affects upper ocean density) and alongshore winds.

The statistical analyses will entail multi-variate spectral techniques (Groves and Hannon, 1968; Bendat and Piersol, 1971) to examine the multiple and partial coherences among the independent (winds and dynamic height) and dependent (sea-level) variables. This technique, analogous to partial and multiple correlation, identifies statistically significant relationships among these variables as a function of frequency (time period). Estimates of dynamic height using the MicroCats will depend upon the numerical technique used to perform the vertical integrations. The choice will be guided by comparisons of dynamic height with high resolution CTD data and consideration of EOF results.

Our analysis will use winds derived from gridded surface pressures available from NOAA's Pacific Fisheries Environmental Group (PFEG) on a 1° by 1° grid at six-hourly intervals. We will follow Luick et al.'s (1987) calculation procedure. These pressure fields are based on a blend of observations and forecasts from numerical models made by the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC). Hourly sea-levels for Seward are available from the Ocean and Lakes Level Division of NOAA and through their homepage. Atmospheric pressure for correcting sea level is collected from a weather package at the Seward Marine Center.

## SCHEDULE

### A. Measurable Project Tasks for FY 98 (October 1, 1997 – September 30, 1998)

| | |
|---|---|
| October 1 | Begin purchase of mooring equipment (MicroCats, etc.) |
| October 15 | Monthly CTD surveys scheduled at mid-month, update homepage as CTD data are processed and edited; prepare wind fields and correct sea level for atmosphere pressure effects as the pressure |
| September 15 | data become available from PFEG |
| November - December, 1997 | Deploy mooring (the mooring will be deployed as soon as instruments can be delivered from the manufacturer) during this month's CTD sampling |
| September 1998 | If FY 99 field monitoring is not funded then recover mooring, send MicroCats for post-calibrations, begin data processing. Otherwise mooring will be recovered in November or December of 1998 when replacement mooring is deployed |

### B. Project Milestones and Endpoints

The data collected as part of this project will be available to a broad community of users. We anticipate that some will want "immediate" access to it. This desire often conflicts with the goal (and required time) of producing data of the highest possible quality. From past experience the final CTD data are generally placed online 1–2 months after collection. The final edited temperature and salinity data from the mooring should be ready three months after instrument recovery. The delays arise because of post-calibration requirements (performed by the manufacturer) and final editing of the data sets (performed at the Institute of Marine Science).

We intend to make much of the data, along with preliminary results, available for rapid dissemination. From a practical point of view this approach is prudent because for many users the differences between the raw and the final edited product are insignificant. We will attach appropriate warnings concerning data quality to both preliminary and final data products. Thus we anticipate making most of the data available on the homepage one month after recovery of the mooring. However, we will not release any data for which there are severe concerns regarding quality unless and until these concerns are resolved. In addition to these general considerations we anticipate the following project milestones:

1. The first objective pertains to basic statistical results which will be made available in both preliminary and final fashion. When the final data product is ready we will update the GAK1 CTD homepage describing these statistics and their relevance to historical GAK1 data.
2. The second objective is to examine rates of change of water mass properties (temperature and salinity) and the phasing of these changes at different depths. This work is largely descriptive and will begin immediately after instrument recovery. Graphical data displays will be made available within 1–2 months of recovery. These will include textural information indicating features of interest. Displays will be updated periodically as new findings emerge. Eventually these results will be merged with those of the third objective.
3. The third objective provides the modal description of system variance. These calculations are straightforward and the results and preliminary interpretations would be made available within two months of mooring recovery. Further interpretation will entail more reflection and likely require completion of the last objective.
4. Four months after recovering the mooring, correlations among winds, corrected sea-level, and upper ocean density will begin. We will first compare dynamic height determined from CTD data with that from the moorings. Combining these results with those from objective 3, we will perform the multiple coherence calculations. We estimate that this objective will be completed two months after beginning.

If the mooring is recovered in September 1998, all objectives will be reached by early April 1999. If the mooring is recovered in November 1998, all objectives will be reached by early June 1999. Similar type analyses and schedules will occur for each year of support. Comparison of the results between years will provide additional indications of statistical variability.

### C. Completion Date

This project will be completed in FY 01.

## PUBLICATIONS AND REPORTS

No manuscripts will be submitted in FY 98. Data and results will be provided via internet as indicated above.

## PROFESSIONAL CONFERENCES

No conference presentations will be made in FY 98 because data collection will not be completed.

## COORDINATION AND RESTORATION

We have discussed aspects of the GAK1 historical data with several investigators supported by the Trustee Council. Many have expressed interest in these data and know how to access it. Other scientists are aware of these data through papers and meetings, (e.g., the American Geophysical Union which serves primarily the US oceanographic community and the North Pacific Marine Science Organization [PICES] comprised of marine scientists from around the Pacific Rim). While we discussed how we would make these data available in previous sections, we welcome advice from the Trustee Council on additional ways to share these data with other investigators and/or the public.

Several UAF scientists are co-investigators on a GLOBEC proposal whose results would complement this proposal. The UAF investigators (Haldorson, Paul, Coyle, Weingartner) along with Royer (Old Dominion University) and Whitledge (University of Texas) have submitted an interdisciplinary proposal to the NSF/NOAA GLOBEC program to examine the Gulf of Alaska shelf ecosystem for the three year period 1998–2000. That proposal calls for six R/V *Alpha Helix* cruises spaced throughout the year to examine the cross-shelf hydrography (including nutrients) and the distribution of phytoplankton, primary production, zooplankton and fish (mainly juvenile salmon and forage fish) in relation to the physical environment.

We see these programs as highly complementary in several ways. First, the cross-shelf hydrography will provide a basis for comparison with variations observed at GAK1. Second, a sufficient number of cross-shelf dynamic height *gradients* (proportional to the ocean transport) would be available (36 in three years) to examine the correlation between this gradient and dynamic height at GAK1. This result will help determine if dynamic height at a single station can provide an index of transport in the Alaska Coastal Current. Third, a comprehensive nutrient data set will be made available for establishing the type of correlations alluded to in the introduction. If significant correlations are obtained at several depths in the water column, then the GAK1 data would be a proxy indicator of historical variations in nutrient concentrations (for some depths).

The GLOBEC proposal makes connections to other investigators. For example, we have offered berth space on the *Alpha Helix* during our GLOBEC cruises to Dr. Robert Day of Alaska Biological Research, Inc., Fairbanks, for his seabird and marine mammal studies. (Dr. Day is submitting a proposal to the Trustees for this project.) Dr. Jeffrey Napp of the NOAA Alaska Fisheries Science Center in Seattle has submitted a GLOBEC proposal to join our cruises to conduct specialized zooplankton hydroacoustic studies. He hopes to a "acoustically tune" a hydroacoustic package to the zooplankton assemblages of the Gulf of Alaska shelf. By so doing he will have an optimally configured instrument that could be incorporated into a mooring for long-term monitoring purposes.

Dr. Geoffrey Wheat, a chemical oceanographer with the West Coast National Undersea Research Center, will contribute an automatic nutrient analyzer for installation on the mooring. At no cost to the Trustee Council, we will install his instrument at the 30 m depth where it will take daily measurements of nitrate, silicate, and phosphate throughout the year. As part of the monthly CTD sampling from the *Little Dipper*, we will collect bottle samples for nutrients that he will analyze for comparison with the instrument results. This in-kind contribution by Dr. Wheat is roughly valued at $8,000. Assuming satisfactory performance of this instrument, his results will constitute the first year-round synoptic nutrient measurements from the Gulf of Alaska shelf. Of equal importance, the GAK1 mooring will provide an opportunity to assess the potential contribution of this technology in long-term ecosystem monitoring.

Additional support for this program will be provided by the University of Alaska Fairbanks' Office of Arctic Research (OAR). OAR will provide funds in FY 98 for the purchase of two of the Microcats for use in this program. Hence, the proposed FY 98 budget reflects an equipment request of four Microcats.

The effort described in this proposal takes a modest, but important step toward achieving the goal of long-term, comprehensive ecosystem monitoring. There are compelling scientific and logistical reasons for believing that GAK1 will be a long-term site and that the sampling will eventually expand to include other disciplines. Resurrection Bay and the adjacent ocean are paradigmatic for much of the Gulf of Alaska shelf and this area is easily accessible by marine scientists at Seward. Although our understanding of chemical cycling and biological processes on this shelf is limited at the moment, programs such as SEA, APEX, and GLOBEC will provide substantial new information for these disciplines. Results from these programs and those anticipated from the work proposed herein will contribute to the design of a comprehensive long-term monitoring strategy. Additional impetus for expanding the monitoring activities at GAK1 will occur as programs at the Alaska SeaLife Center evolve.

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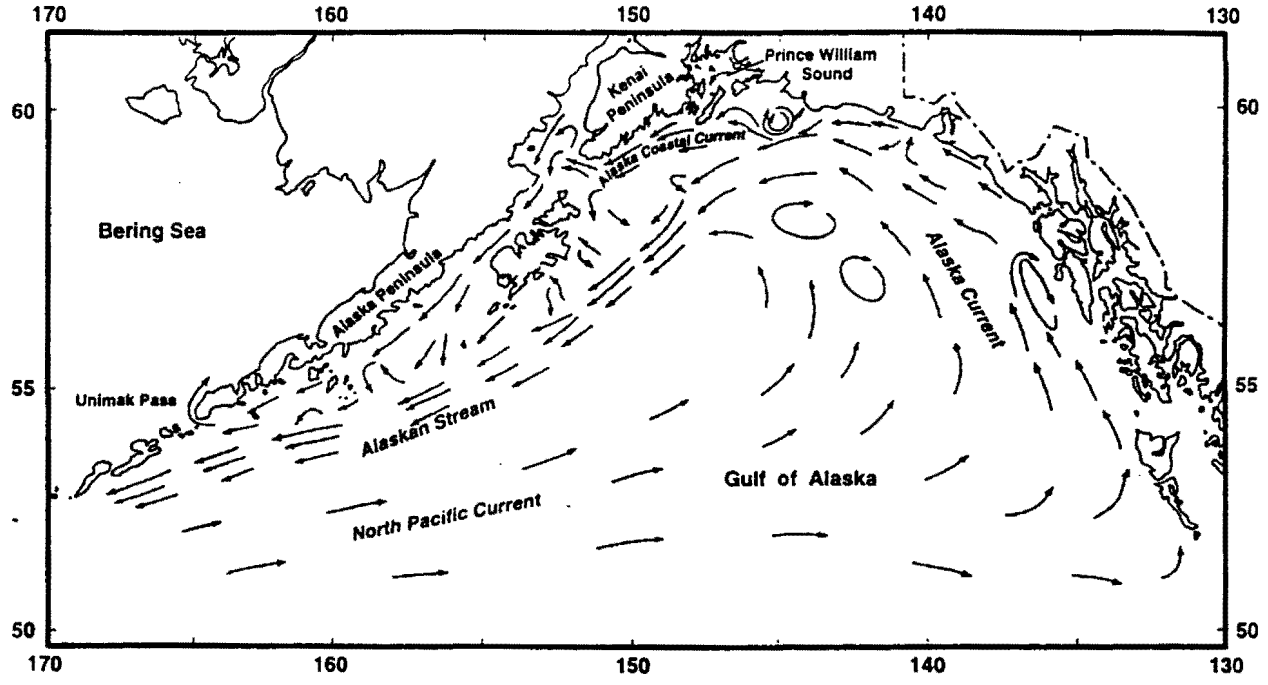


Figure 1. Schematic of the circulation of the Northeast Pacific and Gulf of Alaska (From Reed and Schumaker, 1986).

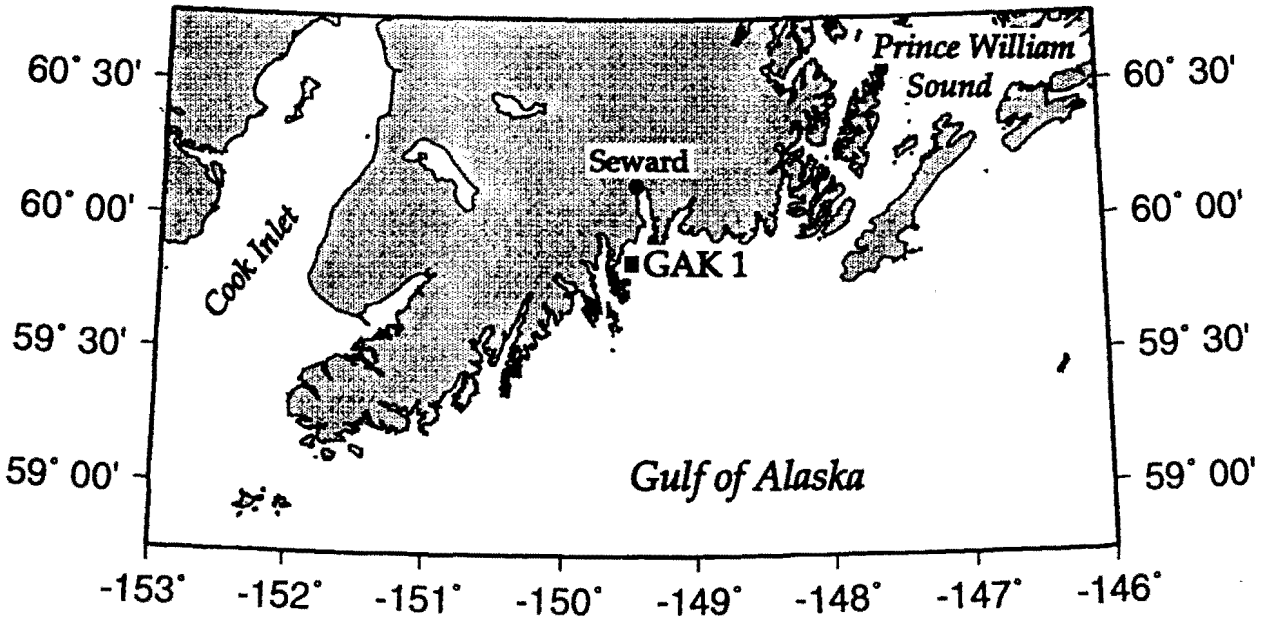


Figure 2. Map showing location of hydrographic station GAK1 in relation to Prince William Sound, Cook Inlet and Seward.

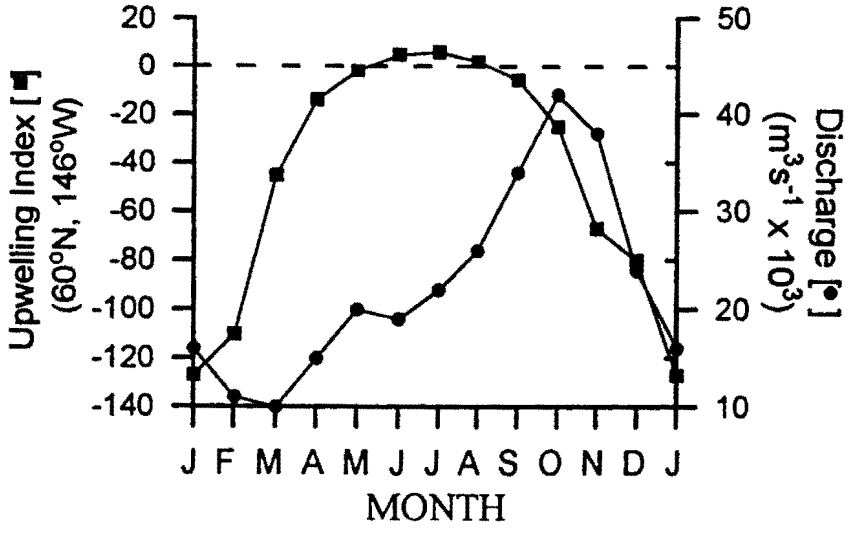


Figure 3. Mean monthly values of the upwelling index (from 1946–1995) and the estimated freshwater discharge (from 1930–1992) into the Gulf of Alaska using the hydrology model of Royer (1982).

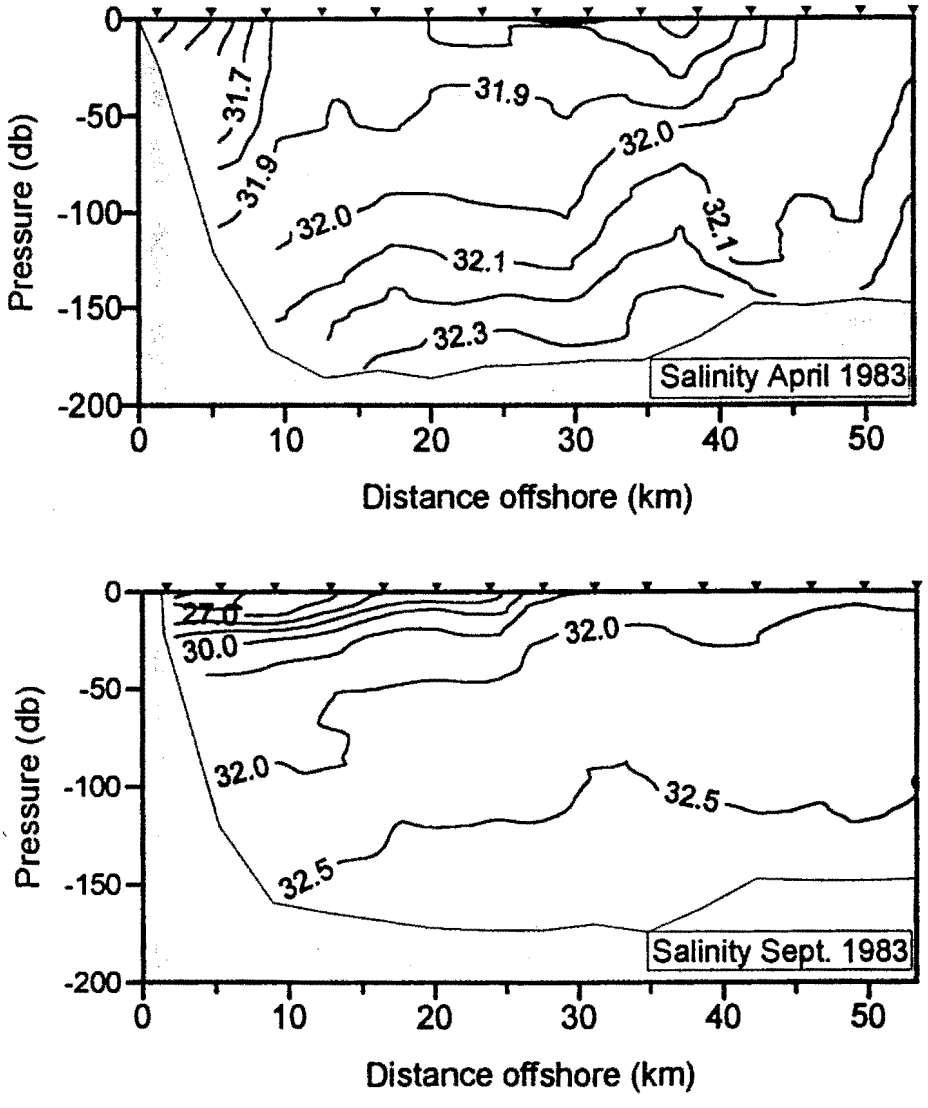


Figure 4. Contours of salinity as a function of depth and position in the Gulf of Alaska on a cross-shelf transect near GAK1. The upper panel is from April 1983 and the lower panel is from September 1993.

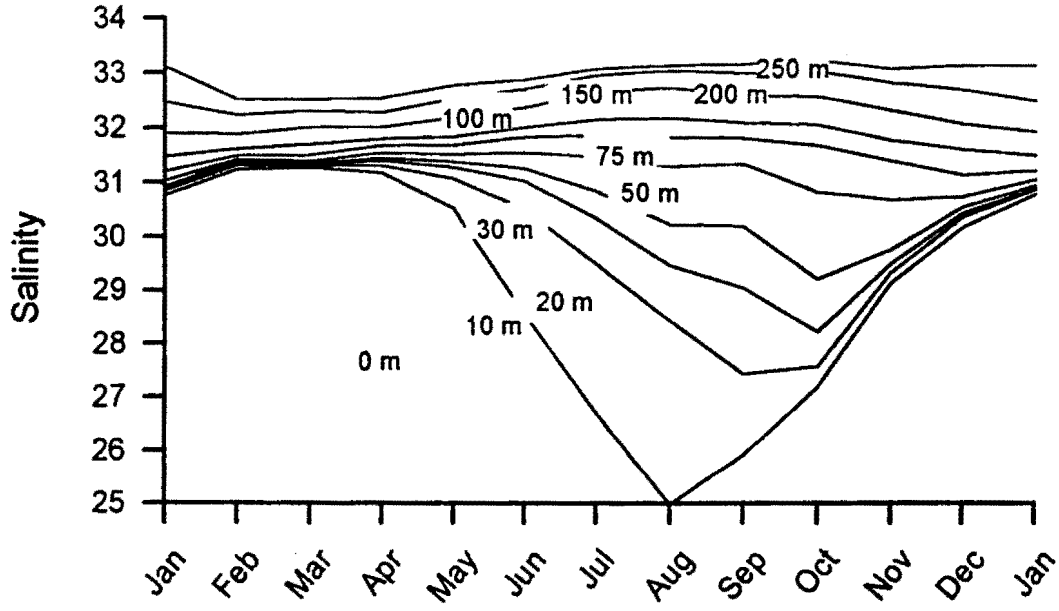


Figure 5. Mean monthly salinity at GAK1 as a function of depth. The means are computed from data collected between 1970 and 1996.

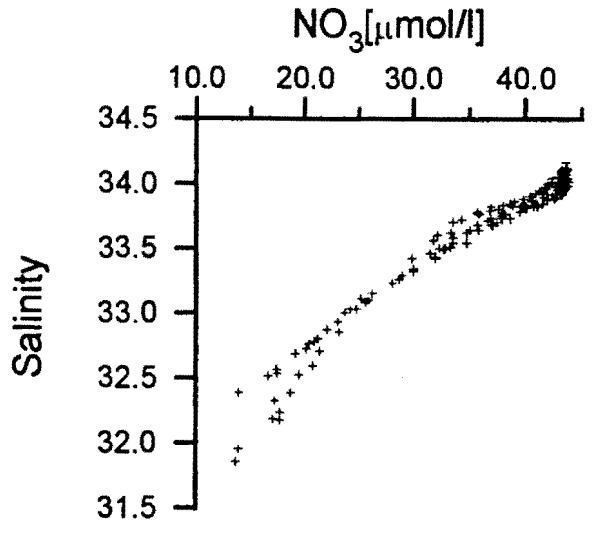


Figure 6. NO3-salinity scatter plot from the shelf and slope of the northwest Gulf of Alaska in May–June 1993.

**1998 EXXON VALDEZ TRUST[illegible]UNCIL PROJECT BUDGET**

October 1, 1997 - September 30, 1998

Approved TC 8-6-97

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $72.1 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $72.1 |
| General Administration | | $5.0 |
| Project Total | $0.0 | $77.1 |
| Full-time Equivalents (FTE) | | 0.0 |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| | | | | | |

Dollar amounts are shown in thousands of dollars.

| Other Resources | | | | | | | | |
|---|---|---|---|---|---|---|---|---|

Comments:

**1998**

Prepared: 1 of 1

Project Number: 98340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

8/28/97

Revision

# 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | | $22.8 | | | | | | |
| Travel | | $3.1 | | | | | | |
| Contractual | | $6.1 | | | | | | |
| Commodities | | $1.9 | | | | | | |
| Equipment | | $23.8 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | | $57.7 | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | Estimated FY 2003 | Estimated FY 2004 |
| Indirect | | $14.4 | | | | | | |
| Project Total | | $72.1 | $94.1 | $62.0 | $62.8 | | | |
| Full-time Equivalents (FTE) | | 0.3 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Funds | | | | | | | | |

Indirect costs are 25% Total Direct Cost, the rate negotiated by the EVOS Trustee Council with the University of Alaska.

**FY 98**

Prepared: 07/10/97

Project Number: 98340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4A
Non-Trustee
SUMMARY

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**

October 1, 1997 - September 30, 1998

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| | Name | Position Description | Budgeted | Costs | Overtime | FY 1998 |
| | T. Weingartner | Professor – P.I. | 1.0 | 6.6 | | 6.6 |
| | S. Sweet | Technician | 0.7 | 4.0 | | 2.7 |
| | E. Shoemaker | Technician | 0.5 | 4.8 | | 2.4 |
| | D. Allen | Technician | 1.8 | 4.6 | 2.6 | 11.1 |
| | | Subtotal | 4.0 | 20.0 | 2.6 | |
| | | | | | **Personnel Total** | $22.8 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| | Description | Price | Trips | Days | Per Diem | FY 1998 |
| | Fairbanks - Seward -- place oceanographic equipment/mooring | 200 | 2 | 10 | 155 | 2.0 |
| | Fairbanks - Anchorage -- Attend EVOS Meeting | 200 | 1 | 5 | 187 | 1.1 |
| | | | | | **Travel Total** | $3.1 |

**FY 98**

Prepared: 07/10/97

Project Number: 98340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4B
Personnel
& Travel
DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| CTD Calibration | 0.6 |
| Shipping of instrumentation | 0.2 |
| Microcat calibrations -- 6 @ $500/each | 3.0 |
| Vessel Charter -- Little Dipper 3 full days @ $500/day, 3 half days @ $250/half-day | 2.3 |
| **Contractual Total** | $6.1 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Batteries, O-rings, tools | 1.0 |
| Safety Shackles and Sling Links for moorings | 0.3 |
| Mooring thimbles | 0.1 |
| Mooring anchor and lashing chain | 0.3 |
| Standard salinity seawater, 6 @ $30/vial | 0.2 |
| **Commodities Total** | $1.9 |

**FY 98**

Project Number: 98340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4B
Contractual & Commodities DETAIL

Prepared: 07/10/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 1998 |
| Seabird Electronic SBE 37 SM w/pressure | 1 | 4,355 | 4.4 |
| Seabird Electronic SBE 37 SM | 3 | 3,155 | 9.5 |
| Edgetech BACS 8202 Acoustic Release | 1 | 10,000 | 10.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $23.8 |

| Existing Equipment Usage: | Number | |
|---|---|---|
| Description | of Units | |

**FY 98**

Prepared: 07/10/97

Project Number: 98340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4B
Equipment
DETAIL

Approved TC 8-6-97

# Harbor Seal Recovery: Controlled Studies of Health and Diet

| | |
|---|---|
| Project Number: | 98341 |
| Restoration Category: | Research |
| Proposer: | M. Castellini/UAF |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | Yes |
| New or Continued: | New |
| Duration: | 1st yr.<br>4 yr. project |
| Cost FY 98: | $152.2 |
| Cost FY 99: | $125.1 |
| Cost FY 2000: | $132.8 |
| Cost FY 01: | $91.4 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Kenai Peninsula |
| Injured Resource/Service: | Harbor seal |


## ABSTRACT

This program begins a long-term study that quantifies the impact of feeding controlled fish diets on the health and body condition of harbor seals. Even though health status biomarkers for marine mammals in Prince William Sound were established during field trials, the critical test on how each marker varies in an individual seal fed differing prey diets has not been conducted. The ability to test these markers directly, under controlled conditions, is now available at the Alaska SeaLife Center. This project proposes to conduct those experiments on harbor seals, but the approach would apply to any of the injured top predators, whether bird or mammal.

## INTRODUCTION

An underlying component of the ecosystem-based research approach supported by the Trustee Council has been the hypothesis that food limitation could be inhibiting the recovery of injured species in the Prince William Sound (PWS). Inherent in this concept is the assumption that food stressed animals can be distinguished by population-wide surveys of critical health parameters. Following this approach, an extensive sampling effort by multiple projects established a series of biomarkers used to profile the health and body condition of wild populations of marine mammals inside PWS. Population health status and body condition indices were, and continue to be, developed and tested for a range of birds, sea otters and seals. On the basis of this wide-ranging effort, reference range values for these health parameters have been established and are being used to compare whole groups of animals across time and space (1-7). This approach is critical to understand how these markers work on a population health level.

Establishing such a series of population-wide health indicators is necessary, but not sufficient, to link their biological activity to known health problems or food limitation. This is because the variance of each indicator over time or under different feeding conditions in any one individual cannot be tested in the field. In the sea otter and seals studies conducted under Trustee Council funding, each individual animal can only be captured once. Recaptures of individuals are extremely rare and certainly not planned. Thus, we can establish the range of reference values for any particular indicator across a whole group of animals, but we do not know how this indicator varies within any given animal under changing conditions of health or feeding status. In human health studies for example, this would be equivalent to establishing the reference ranges for body mass index (BMI) in a study group, but not testing how varying BMI was correlated with changing health status, such as hypertension, coronary heart disease, diabetes or anorexia. It has only been through the careful study of how these health states relate to BMI, that this index can now be used as one of a series of important biomarkers for human health. Thus, medical advice suggests we keep our BMI within given ranges to reduce our chances of health related problems. This type of combination of population monitoring and laboratory study is routine in human health and should be extended to include other species.

The Trustee Council has supported the population monitoring component of health biomarkers for marine mammals in Prince William Sound. Now, with the creation of the Alaska SeaLife Center in Seward, we are in the position to test those biomarkers under controlled conditions, in the same animals over time and under changing experimental conditions. Work on birds using the basic elements of this concept has already been initiated (6).

## NEED FOR THE PROJECT

### A. Statement of Problem

The Restoration Program has established a strong field component that has tested a series of health and body condition biomarkers for many of the top-level predators in the Sound (2,3,5-7), including harbor seals (1,4). Many of these indices are related to metabolic alterations that might occur in animals that were food limited, or stressed. These include

markers for fat, protein and carbohydrate metabolism (fatty acid patterns, blood urea nitrogen, ketone bodies, glucose), water balance (plasma and whole blood water), blubber quality in harbor seals (energetic density, lipid distribution, histology) and total body fat. Other markers have addressed more health or contaminant related issues such as indicators of oil contamination (P450, PAH), whole body inflammatory response (haptoglobin, interleukin), organic residue contamination (PCB) and clinical indicators of disease state (clinical chemistry panels, blood hemograms).

While this significant field-based effort is critical, these markers must now be tested in the laboratory where animals can be fed different food diets and put onto controlled caloric intakes. These markers must also be tested in the same animals over long time periods so that individual variance and seasonal differences can be monitored and experimental conditions altered. For example, we suspect that molting conditions in harbor seals impact haptoglobin levels, an indicator of inflammatory response, but until we follow the same animal through a whole season, we will not be able to test this theory. Finally, these markers must also be tested in animals known to be sick (rehabilitation, stranded) to quantify how they vary with disease or poor health.

**B. Rationale**

The rationale for this project is if we theorize that various health and body condition markers react in the field to ecosystem wide changes in food availability or animal health, then we should be able to quantify those mechanisms in the laboratory under controlled conditions. The SeaLife Center will have research animals that are healthy and can be put onto differing diets of prey and it will have sick animals that are brought in for rehabilitation. Both groups will allow us to examine how these health markers respond to food and health status. Experiments following the same conceptual protocol have been carried out in Europe on harbor seals fed diets of fish that differed in contaminant loads (8). In those studies, it was found that seals fed contaminated fish showed measurable decreases in immune function. In this proposal, we do not suggest feeding contaminated fish, but rather fish of differing energy densities (pollock, herring, salmon and ground fish) and monitoring sick animals that are at the Center for rehabilitation. These "rehab" animals represent seals whose ability to survive in the wild has been compromised and they present a unique view into the biology of "sick" animals that may have been under-represented in our field studies in the Sound.

An additional rationale concerns the "junk food" hypothesis. One of the most popular hypotheses concerning the cause for the decline of marine mammals and birds in Alaskan waters was first voiced at a SeaGrant sponsored workshop in 1991 on whether or not food limitation could account for the observed population patterns (9). At that workshop, the "junk food" hypothesis was proposed. This thesis stated that Alaskan waters had a sufficient biomass of pollock to support the harbor seals and Steller sea lions populations, BUT that the pollock was nutritionally poor compared to other less common species, such as herring and capelin. Because the marine ecosystem of Alaska experienced a "regime shift" in the late 1970s that moved the system from a groundfish/herring based food web to a pollock dominated food web, the high-energy food that pinnipeds used to eat simply disappeared. Thus, the hypothesis proposes that seals and sea lions

may be starving in a sea full of pollock. The presence of The Alaska SeaLife Center will allow us to critically test this hypothesis.

### C. Location

The experiments for this work will be conducted at the Alaska SeaLife Center in Seward. We suspect that similar experiments will be proposed for birds and sea otters. If so, there should be considerable collaboration between the projects and the possibility of significant sharing of resources and personnel. There are also proposed experiments on detailed metabolic alterations in stable isotope ratios in harbor seals that would occur under different feeding regimes (Schell project /071) and will interact closely with this project. The PI (Castellini) has also proposed a program to Alaska SeaGrant for support to conduct identical experiments on Steller sea lions at the Center.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The field work on harbor seals has had integral collaboration with Native communities throughout the Gulf region in conjunction with the BIOSAMPLING program (Project 96244) and we anticipate Native collaboration to continue. Given that the Alaska SeaLife Center, the EVOS Trustee Council, the Alaska Native Science Commission and the Alaska Native Harbor Seal Commission are all currently working on joint scientific collaboration, we expect this project to include involvement with Native communities. However, at this time we cannot predict what form this involvement will take. Since harbor seals are food items for these communities, it is likely that the results of this work will be of interest to the Alaska Native Harbor Seal Commission.

## PROJECT DESIGN

### A. Objectives

This project will quantify the nutritional value of several key Alaskan fish species for harbor seals and will follow health indices over time in both healthy and rehabilitation animals. There are four major objectives:

1. Feed controlled diets of pollock, salmon, herring and several ground fish to harbor seals to quantify the amount of fish necessary to maintain seal body mass.

2. Quantify body condition, health, and blood chemistry biomarker alterations in the seals during the feeding trials.

3. Assess the assimilation efficiency (AE) of the differing fish diets (how much energy can be utilized) for harbor seals.

4. Quantify seasonal, metabolic state, growth status and clinical health impacts on biomarkers and health indices.

## B. Methods

Feeding trials.
Given the possibility that many different species (birds and mammals) may be put onto controlled diets, feeding schedules and timing patterns will be developed in conjunction with the ASLC veterinarian, pinniped staff and research personnel.

We are basing our experimental protocols on models using four to six harbor seals in any given period of time or for any given feeding trial. It is possible that the resident population of harbor seals at the ASLC will be large enough to accommodate additional animals per feeding trial.

Estimating prey or nutrition requirements of a predator population using an energy model necessitates that assimilation efficiency be quantified (10). Assimilation efficiency, which is defined as the proportion of dry matter assimilated from a prey source, is influenced by food quality, meal size, feeding frequency and digestive passage rate (11,13). Recent studies have suggested that assimilation efficiency is low when food quality is low (12,13,14). For example, harp seals (*Phoca groenlandica*) fed Atlantic herring or capelin had a higher AE, and consumed less food, than those fed invertebrates of lower energy density (14). However, conflicting results have been reported for harbor seals (15), and studies of California sea lions fed pollock did not show a large decrease in AE with the lower energy density food (16).

During the feeding experiments to quantify AE, harbor seals will be placed in individual holding tanks. Each feeding experiment will consist of three sections; an acclimation period (approximately 5 d), a collection period (10 d), and an evacuation period (7 d). During each trial, captive seals will be fed a pure diet of one primary prey item during the acclimation and collection periods, keeping other variables such as meal size and feeding frequency constant. The acclimation period allows food to equilibrate in the digestive tract (17) whereas the evacuation period ensures the total removal of the previous prey item. The actual length of the acclimation period will be determined in a preliminary study in which assimilation efficiency will be monitored daily until a stable value is achieved. The design and interpretation of feeding experiments will also need to take into account the potential effects of seasonal variation in AE. During longer term feeding experiments (weeks or months) harbor seals will be kept together in the large natural habitat tanks. In these cases, assimilation efficiency cannot easily be determined, but health indices and body mass, etc. will be measured.

Manganese ($Mn^{++}$) is used as a naturally occurring, inassimilable dietary marker. It's use has been widely applied to pinniped AE studies (13,16,18). To determine the digestibility of food absorbed in the digestive tract of juvenile seals, $Mn^{++}$ concentrations will be analyzed from subsamples of prey items fed to individual seals during the acclimation and collection periods. Feces will be collected during the entire feeding experiment, in order to determine the clearance rate of prey items and fecal $Mn^{++}$ concentrations. Differences in the $Mn^{++}$ concentrations between diet and feces will be used to calculate AE. $Mn^{++}$ concentrations will be determined using atomic

absorption spectrophotometry (18). In addition, diet and fecal samples will be freeze-dried and analyzed for energy (cal/g), nitrogen, total lipid, and ash.

Body condition.
Harbor seals in this study will be measured for mass, length, axillary and hip girth and blubber thickness at the dorsal hips at least weekly for the long term experiments and every other day during the short term AE protocols. Sick animals will be weighed daily in the clinic.

Health markers.
Blood samples for clinical and research health markers will be collected at the times of weighing for all experiments and as allowed by the attending veterinarian for the sick seals. The protocols for blood sampling, collection, storage and analysis have all been tested and verified during the field trials. Basically, several Vacutainers of blood are collected from the intravertebral extradural vein in seals and immediately processed or prepared for storage. The clinical laboratory at the ASLC should be able to handle most of the routine chemistries, but our own analytical procedures will be used for others.

### C. Cooperating Agencies, Contracts, and Other Agency Assistance.

Interactions with other agencies on this project are not known at this time. Given the interest other agencies have expressed in supporting similar feeding trials on different species, this work will have to be organized through the science support staff at the ASLC. Marine Mammal Protection Act permits and internal UAF and ASLC Institutional Animal Care and Use Committee applications will need to be written before this work can begin.

## SCHEDULE

### A. Measurable Project Tasks for FY 98 (October 1, 1997 - September 30, 1997)

We predict that each feeding trial will take several months and work with sick animals may occur at any given time of year. The ASLC may be able to work with pinnipeds as early as March 1998.

| | |
|---|---|
| Oct 1997 - Feb 1998: | Set up $Mn^{++}$ analysis, test laboratory AE protocols |
| March - June: | Initial surveys of health for harbor seals |
| June - August: | Health surveys of stranded and rehabilitation harbor seal pups |
| June - September: | Food trials of healthy animals on mixed fish diets |

### B. Project Milestones and Endpoints

Major milestones will occur in each of the four years of this project, but the four objectives listed above will be carried through the life of the project.

FY 98: Health status of initial groups of harbor seals: feeding trial quality control studies: first year of stranded pups and/or rehabilitation animals: first controlled diet studies.

FY 99: Full year of feeding trials on several species of fish; second year of stranded pups and/or rehabilitation animals.

FY 00: Full year of feeding trials on remaining species of fish or re-trials of previous runs; third year of pups and/or rehabilitation animals.

FY 01: Wrap up of protocols, close out of project, final reports.

**C. Completion Date**

This project will finish on September 30, 2001.

## PUBLICATIONS AND REPORTS

Since this is a new project, there are no current relevant publications. We do not anticipate any full refereed articles in FY 98, however by FY 99 we should be at the stage of publishing short papers on how several of the health biomarkers change through seasons, in healthy vs sick animals, etc.

## PROFESSIONAL CONFERENCES

The PI requests funds to attend a major medical conference each year to work with colleagues who follow such biomarkers in human health studies. Dr. Castellini has a long history of participating in these meetings (Experimental Biology) and they occur each April. Work on this project will be presented at these meetings. In November of 1999, the PI and the primary Ph.D. student on this project request funds to attend the Society of Marine Mammal Biology meetings. We anticipate that the involved students will attend several other smaller or regional meetings throughout the life of this project. Funds are also requested for the PI and one student to attend the annual EVOS workshops each year.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

As noted above, we anticipate that there will be several projects looking at controlled diets in birds and mammals at the ASLC. These multiple experiments will require close coordination from the associated principal investigators, the ASLC animal staff, veterinarian and staff, science officer and executive director.

**PROPOSED PRINCIPAL INVESTIGATOR**

Dr. Michael Castellini
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FAX: (907) 474-7204
e-mail: mikec@ims.alaska.edu

Revision 5/97

Approved TC 8-6-97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $123.4 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $123.4 |
| General Administration | | $8.6 |
| Project Total | $0.0 | $132.0 |
| Full-time Equivalents (FTE) | | 0.0 |
| Other Resources | | |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| | | | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

TOTAL PROJECT COST:

132.0
20.2 ASLC Bench Fees
$152.2

**1998**

Prepared: 6/25/97

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

6/25/97

## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 1998 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
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| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 0.0 | 0.0 | 0.0 | |
| | | | | | **Personnel Total** | $0.0 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
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| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $0.0 |

**1998**

Prepared: 6/25/97

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game

FORM 3B
Personnel
& Travel
DETAIL

6/25/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed FY 1998 |
|---|---|
| Description | |
| University of Alaska | 123.4 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $123.4 |

| **Commodities Costs:** | Proposed FY 1998 |
|---|---|
| Description | |
| **Commodities Total** | $0.0 |

**1998**

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game

FORM 3B
Contractual & Commodities DETAIL

Prepared: 6/25/97



6/25/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 1998 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

| **Existing Equipment Usage:** Description | Number of Units | Inventory Agency |
|---|---|---|
| | | |

**1998**

Prepared: 6/25/97 6/97

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game

FORM 3B
Equipment
DETAIL

6/25/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Personnel | | $67.5 | | | | | | |
| Travel | | $15.1 | | | | | | |
| Contractual | | $11.1 | | | | | | |
| Commodities | | $5.0 | | | | | | |
| Equipment | | $0.0 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | | $98.7 | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | Estimated FY 2003 | Estimated FY 2004 |
| Indirect | | $24.7 | | | | | | |
| Project Total | | $123.4 | $116.9 | $124.1 | $85.4 | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 2.4 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Funds | | | | | | | | |

Comments:

Indirect costs are 25% Total Direct Cost, the rate negotiated by the EVOS Trustee Council with the University of Alaska.

Student salaries include $5544 in tuition each.

**1998**

Prepared: 6/25/9778

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game

FORM 4A
Non-Trustee
SUMMARY

6/25/97

## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 1998 |
| M. Castellini | Associate Professor – P.I. | | 2.9 | 7.4 | | 21.3 |
| J. Castellini | Research Associate | | 2.3 | 3.8 | | 8.7 |
| Vacant | Ph.D. Student | | 12.0 | 1.7 | | 19.9 |
| Vacant | M.S. Student | | 12.0 | 1.5 | | 17.6 |
| | Subtotal | | 29.2 | 14.4 | 0.0 | |
| | | | | | **Personnel Total** | $67.5 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| 6 R/T Fairbanks–Seward | 200.0 | 6 | 87 | 138.0 | 13.2 |
| 2 R/T Fairbanks–Anchorage, EVOS Workshop | 150.0 | 1 | 4 | 120.0 | 0.6 |
| 1 R/T Fairbanks–San Francisco, Experimental Biology Meeting, April 1998 | 600.0 | 1 | 5 | 130.0 | 1.2 |
| | | | | **Travel Total** | $15.1 |

**1998**

Prepared: 6/25/97 6/97

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game

FORM 4B
Personnel
& Travel
DETAIL

6/25/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Chemical analysis of blood samples @ $35 | 10.5 |
| Long distance phone and communication | 0.6 |
| **Contractual Total** | $11.1 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Laboratory expendables for collection of blood samples | 2.5 |
| Laboratory expendables for analysis of blood samples | 2.5 |
| **Commodities Total** | $5.0 |

**1998**

Prepared: 6/25/97

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game

FORM 4B
Contractual & Commodities DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| New Equipment Purchases<br>Description | Number of Units | Unit Price | Proposed FY1998 |
|---|---|---|---|
| | | | |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | New Equipment Total | $0.0 |

| Existing Equipment Usage:<br>Description | Number of Units |
|---|---|
| | |

**1998**



Prepared: 6/25/97

Project Number: 98341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Agency: Alaska Dept. of Fish and Game:

FORM 4B
Equipment
DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $18.9 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $18.9 |
| General Administration | | $1.3 |
| Project Total | $0.0 | $20.2 |
| Full-time Equivalents (FTE) | | 0.0 |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| | | | | | |

Dollar amounts are shown in thousands of dollars.

| Other Resources | | | | | | | | |
|---|---|---|---|---|---|---|---|---|

Comments:

Contractual funds are for payment of bench fees at the Alaska SeaLife Center.

**1998**

Prepared: 1 of 1

Project Number: 98341
Project Title: Bench Fees: Harbor Seal Recovery/Health and Diet
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

8/28/97

Approved TC 8-6-97

# Publication of an Indexed Bibliography of the Genus Ammodytes (Sand Lance)

| | |
|---|---|
| Project Number: | 98346 |
| Restoration Category: | Research |
| Proposer: | R. Armstrong/UAA, M. Willson/USFS, M. Robards/DOI |
| Lead Trustee Agency: | USFS |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | No |
| New or Continued: | New |
| Duration: | 1st yr.<br>1 yr. project |
| Cost FY 98: | $5.4 |
| Cost FY 99: | $0.0 |
| Cost FY 2000: | $0.0 |
| Cost FY 01: | $0.0 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Worldwide |
| Injured Resource/Service: | Common murres, pigeon guillemots, pink salmon, marbled murrelet, Kittlitz's murrelets, cormorants |


## ABSTRACT

Pacific sand lance is important in the diet of birds, fish, and sea mammals. Little is known about this species in Alaska. Much of the information is found in agency reports and gray literature, which are usually not attainable by library electronic searching methods. This project will review all studies of Pacific sand lance in Alaska and recommend further research. Studies done outside of Alaska will be integrated where local knowledge is lacking. The bibliography will cover all published and unpublished references on the genus *Ammodytes*. Key words and a summary of information will be provided for each reference. All references will be incorporated into a taxonomic, geographic, and subject index.

# INTRODUCTION

This proposal requests funds to publish an indexed bibliography on the genus Ammodytes (Sand Lance) coupled with a review of studies on Pacific sand lance in Alaska. The bibliography will include all of the published and unpublished reports that we can find. Each reference will include a list of key words and a summary of pertinent information on sand lance. All references will be incorporated into an index by taxon, geographic area and subject. A review of what is known about the Pacific sand lance in Alaska and recommendations for further studies will be included.

For over a year, Martin Robards in Anchorage and Mary Willson and Robert Armstrong in Juneau have been gathering references on the genus Ammodytes. We only recently discovered each other efforts' and decided to cooperate on a joint publication. Our combined efforts will be incorporated into an electronically accessible bibliography with key words and a written published bibliography and review that includes key words, summaries and index. This proposal seeks funds for the written publication only.

Another project to conduct a sand lance literature review and synthesis was submitted as a restoration proposal for the fiscal year 1997 (number 97235). This proposal was turned down by the Trustee Council. We feel our proposal is different because it is much cheaper ($5,000 vs $42,300), and it requests publication costs only and does not include any salary.

# NEED FOR THE PROJECT

## A. Statement of Problem

Pacific sand lance were largely ignored in the initial studies after the *Exxon Valdez* oil spill. No studies of sand lance were presented in the proceedings of the *Exxon Valdez* oil spill symposium. However a brief mention of its occurrence in Prince William Sound was made by Laur and Haldorson (1996) and Norcross and Frandsen (1996). Also sand lance were mentioned as being important forage for Black-legged Kittiwakes (Irons 1996), Marbled Murrelets, Common Murres, Horned Puffins, Tufted Puffins (Kuletz 1996, Piatt and Anderson 1996) and Pigeon Guillemots (Oakley and Kuletz 1996).

More recently, however, the importance of Pacific sand lance within the Prince William Sound ecosystem has been well emphasized by several studies presented at the 1996 International Role of Forage Fishes in Marine Ecosystems and by studies conducted under the APEX project. In particular, sand lance may be critical to the maintenance of two species listed as not recovered in the Exxon Valdez Oil Spill

Restoration Plan: Pigeon Guillemots (Hayes and Kuletz 1996) and Marbled Murrelets (Burkett 1995). Pacific sand lance are also considered to be an important part of the diet of harbor seals, Dolly Varden, salmon, Common Murres and Kittlitz's Murrelets.

The reasons for these bird species' reduced survival are under investigation by Trustee projects and could be related to a reduced availability of prey, included sand lance. Because of the Pacific sand lance's behavior -- i. e. nearshore habitation, burrowing in substrate at night and during winter -- it is likely the species has been negatively impacted from the spilled oil. In partial response to this possibility and to the documented importance of sand lance as a forage fish in Prince William Sound, a project on the ecology and demographics of sand lance is being conducted in lower Cook Inlet. This Trustee funded project is expected to conclude in FY 99. Since little is known about Pacific sand lance in Alaska, a literature search on this and related species has been ongoing and is nearing completion. There is a need to obtain funding to publish the resulting bibliography and review.

### B. Rationale/Link to Restoration

The proposed project would provide researchers with what is known about Pacific sand lance and related species. This would help several Trustee-funded projects by providing ready access to comprehensive information on an important forage fish as well as several Prince William Sound predators.

### C. Location

To be determined, but may be published as a Biological Paper of the University of Alaska, Institute of Arctic Biology -- Fairbanks or as a Pacific Northwest Research Station General Technical Report.

## COMMUNITY INVOLVEMENT

This project does not involve field work. Research agencies, science centers, public schools, native corporations, universities, environmental organizations and others will have access to the publication.

## PROJECT DESIGN

### A. Objectives

1. To publish an indexed bibliography on the genus Ammodytes. The bibliography will include all published and unpublished reports that we can find. Each citation will

include key words and a summary of the work. An index by taxon, geographic area, and subject will be included. All work related to Prince William Sound will be identified.

2. To publish, with the bibliography, a related article covering what is known about the Pacific sand lance in Alaska. Subjects covered will include life history, importance, distribution, vulnerability to pollution (including oil) and others. Information from studies done on related species will be integrated if it enhances our ability to understand the Pacific sand lance.

### B. Methods

Bids will be obtained from printers associated with the Biological Papers of the University of Alaska. In addition, other referred sources will be contacted for bids.

### C. Cooperating Agencies, Contracts, and Other Agency Assistance

No contracts are anticipated. The project is a cooperation between the University of Alaska, U. S. Forest Service and U. S. Geological Survey.

## SCHEDULE

### A. Measurable Project Tasks for FY 98

| | |
|---|---|
| Oct. 1 - Dec. 31 1997: | Finish Key Words and Summaries |
| Nov 1 - Feb 29 1998: | Write final report and submit for review |
| Mar 1 - Sept. 30 1998: | Send report to printer |

### B. Project Milestones and Endpoints

| | | |
|---|---|---|
| December | 1997: | Key Words and Summaries completed. |
| March | 1998: | Final report completed. |
| September | 1998: | Report submitted to printer. |

### C. Completion Date

The completion date for submitting the project for publication would be during FY 98.

## PUBLICATIONS AND REPORTS

Armstrong, R. H., M. F. Willson and M. Robards. 1998. Indexed bibliography of the genus *Ammodytes* (sand lance) to 1997. Biological Papers of the University of Alaska.

Willson, M. F., M. Robards and R. H. Armstrong. 1998. A review of Pacific sand lance (*Ammodytes hexapterus*) studies in Alaska. Biological Papers of the University of Alaska.

A computer bibliography with key words will also be produced (not directly connected to the funding request).

## PROFESSIONAL CONFERENCES

## NORMAL AGENCY MANAGEMENT

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Coordination is ongoing between the University of Alaska, U. S. Forest Service and U. S. Geological Survey in acquiring references.

## PROPOSED PRINCIPAL INVESTIGATORS

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**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**

October 1, 1997 - September 30, 1998

Approved TC 8-6-97

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $5.0 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $5.0 |
| General Administration | | $0.4 |
| Project Total | $0.0 | $5.4 |
| Full-time Equivalents (FTE) | | 0.0 |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
|---|---|---|---|---|---|
| | | | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

**1998**

Prepared: 1 of 1

Project Number: 98346
Project Title: Publication of Sand Lance Bibliography
Agency: USFS

FORM 3A
TRUSTEE
AGENCY
SUMMARY

9/9/97

# 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | |
| Travel | | |
| Contractual | | 5,000 |
| Commodities | | |
| Equipment | | |
| Subtotal | | |
| Indirect | | |
| Project Total | | |
| Full-time Equivalents (FTE) | | |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 |
|---|---|---|---|
| | | | |

Dollar amounts are shown in thousands of dollars.

Comments: $5,000 printing costs of indexed bibliography of the Genus Ammodytes wide review.

1998

Prepared: 5 of 8

Project Number: 98 346
Project Title: Publication of Sand Lance Bibliography
Name: Robert A. Armstrong

FORM 4A
Non-Trustee
SUMMARY

4/8/97

Revised 6-27-97
Approved TC 8-6-97

# Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Composition and Quality at Different Trophic Levels

| | |
|---|---|
| Project Number: | 98347 |
| Restoration Category: | Research |
| Proposer: | R. Heintz/NOAA |
| Lead Trustee Agency: | NOAA |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | No |
| New or Continued: | New |
| Duration: | 1st yr.<br>3 yr. project |
| Cost FY 98: | $110.6 |
| Cost FY 99: | $92.6 |
| Cost FY 2000: | $35.3 |
| Cost FY 01: | $0.0 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | Various |


## ABSTRACT

This project will begin the systematic development of fatty acid profiles and lipid class analysis to identify diet differences and quality in predators on several trophic levels. The spatial variability of fatty acid profiles in herring and sandlance will be related to their prey, and the nutritional consequences of dietary differences will be examined. Results of the fish studies will benefit APEX (Project /163) investigators by demonstrating the utility of fatty acid analysis for establishing dietary and energetic differences between aggregates of forage fish.

## INTRODUCTION

This project seeks to expand the utility of fatty acid (FA) analysis for estimating diet composition, by relating FA compositions in forage fish to their prey and examining the nutritional condition of these animals through lipid class analysis. Iverson et al (in press) have indicated that FA profiles in seals in Prince William Sound (PWS) reflect the profiles found in their prey. In view of its promise, the utility of FA analysis for estimating diet composition warrants investigation in other predators. However, Iverson et al. (In press) clearly demonstrate that FA profiles in herring vary with location and size, but the spatial scale of this variability has not been defined. Before this technique can be applied to other predators the sources of variation in the FA profiles of their prey must be quantified since a predator's FA profile will be influenced by the FA available in its foraging range. The studies described below are designed to evaluate the spatial and temporal scales of variation in the FA profiles of important forage fish and demonstrate use of lipid class analysis for interpreting the biological meaning of observed dietary differences.

FA can be viewed as the energetic currency that is exchanged when predators consume prey. After consumption, some fraction of the consumed FA are used to provide energy for the Krebs cycle, while surplus FA are distributed via the blood stream to fat depots located throughout the organism. In many cases, essential FA (FA that cannot be synthesized) identified in predator FA profiles can be used to directly link predators with their prey. This mechanism provides opportunities to identify recently consumed prey by analysis of the FA profiles in the predator's blood, as well as the FA profile of all prey integrated over time by analysis of FA composition in depot fats.

Examination of the relative abundance of lipid classes in organisms provides a measure of their nutritional condition. Lipids can be classified by their structure into several classes. Each class represents lipids used for either membranes, energy reserves, structural elements or hormones. Comparing the relative abundance of the energy reserve class, triacylglycerides (TAG), to the total amount of lipid provides a measure of the relative amount of energy reserve, thus the nutritional condition of the specimen. Combining observations of dietary differences with evaluations of nutritional condition can lead to extremely powerful interpretations of efficiencies in predator prey relationships. This power is easily obtained since FA analysis for estimating prey composition is most sensitive when performed on the neutral lipid portion of the total lipid composition, thus lipid class analysis is the first step to analyzing FA composition.

We propose two field surveys designed to demonstrate 1) the spatial and temporal scales of variation in the FA profiles of important forage fish in PWS, and 2) the analysis of FA profiles and lipid class analysis for examining the nutritional consequences for predators consuming different diets. These projects are the first steps in the systematic development of these techniques for examining broad scale trophic relationships. Specifically, the studies provide detailed information on the spatial and temporal variability of FA profiles in herring and sandlance as well as measuring the consequences of dietary differences by evaluating the availability of surplus energy. Samples, collected from different locations in PWS in July, 1997 by APEX 971638A investigators, will be

technique with another marine mammal and provide detailed information on the spatial variability of fatty acid profiles in marine mammal prey. The field project examines the influence of location, and age on the fatty acid composition of herring and sandlance and measures the consequences of dietary differences by evaluating the availability of surplus energy. Samples, collected from PWS in July, 1997 by APEX 971638A investigators, will be processed in FY 98. For the laboratory project, we propose to examine how changes in diet affect the fatty acid and lipid class compositions of blood and blubber in captive sea lions, by sampling both diet and sea lions as the diets are varied over a 45 week period. The laboratory project will begin as soon as sea lions are available for study at the Sea Life Center in Seward, Alaska. The herring data from the proposed field study can ultimately be coupled with sea lion data from the lab study to extend the analysis of fatty acids to wild sea lions.

## NEED FOR THE PROJECT

### A. Statement of the Problem

Trustee sponsored projects including APEX, SEA and NVP focus on understanding trophic relationships, but depend on diet information that do not adequately quantify energy transfer between predator and prey. Diet studies are typically underpowered, because parametric techniques for estimating sample sizes are not well understood (Ferry and Cailliet 1996). Even if analysis of stomach contents could provide precise estimates of diet over spatial and temporal scales, the data are biased by differences in prey digestibility and the assumption that stomach contents at collection represent diets averaged over time. Marine mammal diets are usually assessed by examining scats, which have many of the same biases as stomach contents. In addition, diet evaluation by stomach or fecal content analysis provides only an indirect method for estimating the amount of energy transferred between predator and prey, since measurements of energy density and digestibility estimate energy availability rather than energy acquisition.

Fatty acid analysis for estimating prey composition may have tremendous potential for avoiding the biases observed in stomach content or scat analysis, while lipid class analysis provides a more direct measure of energy acquisition in predators. The application of fatty acid analysis in seals was reported in Restoration Project 95064 (Frost et al. 1996). In addition, the fatty acid profiles in predators has been found to reflect the profiles in prey in a number of feeding studies involving herring (Gatten et al. 1983), cod (dos Santos et al. 1993), chinook salmon (Kennish et al. 1992) and pike (Schwalme 1992). However, these latter studies have been under laboratory conditions where developmental stages, diets and environments have been tightly controlled, and field application remains to be examined. Similarly, lipid class analysis coupled with fatty acid analysis has been used to study trophic relationships in closed systems (Fraser 1987). Lipid class analysis measures nutritional condition by expressing the TAG content as a proportion of total lipid, with high proportions of TAG indicating increased amounts of storage lipid (Fraser 1987).

The success of fatty acid analysis for estimating prey composition depends on understanding the nutritional requirements of the predator, its foraging behavior, and the fatty acid composition of

its prey. Iverson et al. (In press) demonstrated that herring in PWS have fatty acid profiles that vary both spatially and morphometrically. These differences are thought to arise from dietary differences in herring from different locations, and their consumption of different sized prey. Phocid seals and their prey may be a good model system for this technique since seal foraging ranges may be quite small with respect to the scale of spatial variability in their prey (Frost et al. 1996), while fatty acid profiles of less selective predators, or predators that forage over broad spatial scales may be more difficult to match to prey. Also, establishing direct links between prey and predator is contingent on tracing the route of essential fatty acids from prey to predator.

Systematic development of a trophic relation that can be examined by fatty acid and lipid class analysis requires identification of essential fatty acids in the predator, and examination of the sources of variability in the fatty acid profiles of its prey. Essential fatty acids are best identified in controlled feeding trials where the fatty acid composition of the predator can be evaluated over time and related to known changes in the fatty acid composition of its prey. Ideally, feeding trials will survey several developmental stages in the predator since, fatty acid profiles will change in response to ontogenetic demands (Leger 1985). Sources of variation in the fatty acid profiles of the prey are examined by evaluating the spatial and ontogenetic scales of variation in each of the different prey and relating them to the prey selectivity and foraging range of the predator.

The power of lipid class and fatty acid analysis to examine trophic relationships will ultimately lie in the ability to hindcast predator diets from the fatty acid composition of its depot fats. Ideally, predator fatty acid profiles are compared to a library of prey profiles, and the relative abundance of each prey item in the predator diet is predicted with some measure of statistical confidence. Currently Tree Structures (CHART) are used to specify prey compositions in predator diets, but no statistical confidence is associated with the compositions identified by this technique, nor are the relative contributions of the prey predicted. Development of a parametric model for hindcasting diet composition must wait until the sources of variation in prey fatty acid profiles are better understood. General application of such a model to multiple trophic levels requires careful quantification of the fatty acid profiles of mid-level consumers as both prey and predators. The work proposed here will lead to systematic development of such a model.

**B. Rationale/Link to Restoration**

We propose to begin systematic development of the trophic relationship between sea lions and their prey by identifying essential fatty acids in sea lions using a controlled feeding study, and examining the spatial and ontogenetic scales of variation in the fatty acid profiles of wild herring. The sea lion feeding study will establish the use of this technique for examining sea lion diets, and the herring field collections will address questions posed by Restoration Study 97064. Consequently, the proposed herring sampling will complement plans made by Restoration Study 97064 and provide those investigators with increased power to resolve harbor seal diets. Like Restoration Study 97064, our herring be collected by APEX investigators. By using the herring sampling program proposed by APEX and comparing the herring collections with simultaneously

sampled sandlance and zooplankton collections, we can provide APEX investigators with a cost-effective analysis of energetic relationships between forage fish and their prey. Thus, the two projects proposed here have direct links to a number of ongoing and proposed projects, and will also provide information that is of interest to other Trustee programs.

The importance of understanding the relation between diet and nutritional condition in sea lions is indicated by recent hypotheses concerning the link between recent population declines and diet quality. Merrick and Calkins (1996) showed that sea lion diets have changed since population declines were first observed. Declining populations have demonstrated increasing dependence on pollock, a low fat prey, while more stable populations have more diverse diets (Merrick et al. In Press). Population declines appear to result from the loss of young individuals, presumably through poor nutrition. Substantiation of this hypothesis is impeded because traditional methods of examining diets in sea lions provide little information on individual diet differences among sea lions residing in the same location.

Marine mammals with their large reservoirs of depot fat are the animals most likely to benefit from this analysis, since their diets cannot be adequately characterized by traditional methods. The study proposed here supplements the proposed, *"Pinniped Muscle Response To Diet"* project, by providing detailed analysis of both the fatty acid profiles of sea lion food and blubber, and quantifies the consequences of changes in diet on the relative abundance of surplus fats. While sea lions were not directly injured by the *Exxon Valdez* oil spill they are a threatened species, and their populations in PWS have experienced dramatic declines since the spill (NMFS 1995). In addition, seals and sea lions are important prey to killer whales, so combining results from this proposal with Restoration Study 95064 provides a basis for extending this work to killer whales. Finally, variation in the fatty acid composition of different blubber layers (Freheim et al. 1994, Koopman et al. 1996) has not been systematically evaluated. By systematically varying the diet of the sea lions, we can examine the consequences of different diets on the nutritional condition of the animals and determine if stratification in the fatty acid composition of blubber reflects temporal variation in diet.

A stated objective of the Trustee funded APEX project is to examine the differences in forage fish diets and determine the consequences of the differences at the individual and population level. We propose to supplement the cruder evaluations of energetic content in herring and sandlance proposed under the APEX studies with analysis of lipid class composition and fatty acid profiles, since lipid class composition provides a direct measure of the energetic consequences of different diets (Fraser 1987). Examination of the fatty acid profiles of herring, sandlance and their prey from different locations in PWS will quantify the spatial range of diet variability because dietary differences are reflected in fatty acid profiles. Samples will be collected by APEX 97163A investigators whose design includes fine scale sampling of sandlance, herring and their prey in two disparate locations in PWS. This design allows comparison of fatty acid profiles over several spatial scales, as well as comparison of profiles in allopatric and sympatric sandlance and herring.

Besides supplementing the work under APEX 97163A, the proposed project provides Restoration

Study 97064 with information on the foraging range of seal prey. Plans for Restoration Study 97064 call for examining fatty acid profiles of herring collected in Northeast PWS near Port Gravina area and south central PWS near Port Chalmers. The resolving power of Restoration Study 97064 will be greatly enhanced by the projects described here. The projects proposed here further benefit Restoration Study 97064 by examining herring in southwestern PWS, an area with important seal populations that has not been examined by 97064.

### C. Location

This project depends on samples collected either at the Sea Life Center in Seward, Alaska or on forage fish samples collected from various location in PWS. All the samples will be shipped to and processed in Auke Bay, Alaska.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

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. The project uses existing agency labor to process and analyze the samples. Interpretations of differences in the nutritional condition of herring between different locations in PWS can be correlated with traditional knowledge of differences in the palatability of herring from different locations.

## PROJECT DESIGN

### A. Objectives

The main objectives of the field and laboratory projects are listed below. The forage fish study can begin immediately in FY98 using samples collected in July, 1997 by APEX investigators. While initiation of the sea lion feeding study depends on the the availability of test animals at the Sea Life Center. The results of the field project will directly benefit APEX 97163A investigators by providing them with detailed energetic data on two important forage fish. The herring collections made by Restoration Study 97064 will complement those proposed here leading to greater understanding of the spatial variability of fatty acid profiles. Finally, the results of the sea lion feeding study can be combined with the herring data sets to begin wild sea lion studies.

FY 98 Examine the spatial scale of variability in the fatty acid profiles of herring, sandlance and their prey.

1. Determine the spatial range of variation in fatty acid profiles of herring and sandlance and relate the differences to nutritional condition.

2. Relate the spatial scale of variation in herring and sandlance fatty acid compositions to the spatial scale of variability in their potential prey.

FY 99 Examine the consequences of low and high fat diets for fatty acid profiles and TAG availability in sea lions.

3. Determine if the fatty acid composition of sea lion diets is reflected in their blood and blubber and relate dietary lipid to nutritional condition.

4. Determine if variability in the fatty acid composition of different blubber layers reflects temporal variability in sea lion diets.

**B. Methods**

Spatial Scale of Variability in Herring and Sandlance Fatty Acid Profiles (Objectives 1 and 2)

This project supports APEX Project 97163A which is designed to examine the biomass distribution of forage fish and their prey in different portions of PWS. Biomass distributions are examined by hydro acoustic surveys along transects within study areas in either northeastern or southwestern PWS. Targets identified by sonar are sampled with trawl nets to determine species composition. In certain locations, macro plankton samples will be drawn to identify prey available to forage fish, additionally, samples of fish from the same locations will be preserved to examine their stomach contents.

We propose collecting adult sandlance and herring from 2 developmental categories, young of the year, and age > 1+ from each trawl sample where sufficient numbers of these species are recovered to warrant sampling. Age 1+ herring, and sandlance samples will all be taken from the modal length classes of each species. APEX investigators will be responsible for sample collection, storage and shipment to Auke Bay. Fish will be stored in individual airtight containers and labeled with unique sample numbers and codes reflecting the trawl location and date. Priorities for processing samples will be assigned by conferring with APEX investigators and evaluating the distribution of forage fish biomass after the cruise has been completed. The highest priorities will be assigned to samples taken from discrete aggregates of fish with biomass densities near or exceeding 2.5 g fish/$m^2$ in the locations where detailed macro plankton collections will be made. No more than 10 fish samples from the same category will be processed from 3 such aggregates in both parts of PWS, providing a total of 180 whole fish samples for fatty acid analysis. Note that young of the year herring samples may represent composites of several individuals to ensure adequate sample sizes for lipid analysis.

At locations where macro zooplankton are sampled, collections will be made to examine the fatty acid composition of the prey field and examine the spatial variability of their fatty acid profiles. APEX investigators will be making detailed evaluations of the prey fields, near Port Fidalgo, in northeastern PWS and near Icy Bay in southwestern PWS. In each of these locations, we

. propose collecting 2 replicate zooplankton tows, hauled from 60 m with a 0.5 m diameter net. There will be 8 separate stations providing a total of 16 zooplankton collections from each part of PWS. Distances between the stations will be recorded and are estimated to range between 0.5 and 4.0 km. Zooplankton composition in each collection will be determined from samples collected simultaneously by APEX investigators. Zooplankton from each tow will be stored in airtight containers, labeled with the date and location of the tow and immediately frozen. At least 2 g (wet weight) of zooplankton from each collection will be processed by methods described below to determine their lipid class composition and fatty acid profiles.

Analysis of the fatty acid composition data relies on the assumption that differences in fatty acid profiles reflect dietary differences. This assumption will be investigated in detail at a later date, however its reliability is demonstrated by a number of studies that relate diet and fatty acid composition in Atlantic herring ( Owen and Middleton 1977, Gatten et al. 1983, Fraser et al 1987, and Navarro et al. 1993). The sources of the differences in diet that are revealed by differences in fatty acid profiles cannot be identified unless the fatty acid profiles of all prey are known. This analysis is outside the scope of this proposal. All efforts will be made to correlate the results of our analyses with evaluations of herring diets performed on samples of stomach contents collected and examined by APEX investigators.

Fatty acid profiles of each fish collection will be tested for differences by multivariate analysis of variance (MANOVA) to determine the spatial scale of variation. The following model will be used to test the null hypothesis that fatty acid profiles do not differ between sampling locations:

$$\mathbf{P}_{ijk} = \mathrm{L}_i + \mathrm{A}_j(\mathrm{L}_i) + \epsilon_{ijk}$$

where $\mathbf{P}_{ijk}$ is the vector containing the relative concentrations of each of the fatty acids observed in the $k^{th}$ fish collected from aggregate $j$ in portion $i$ of PWS, and $\mathrm{A}_j(\mathrm{L}_i)$ indicates the $j^{th}$ aggregate is a random variable nested in the $i^{th}$ portion of PWS. Only similar species or developmental stages will be compared. A similar model will be used to examine spatial variability in zooplankton fatty acid profiles. The consequences of differences in fatty acid profiles will be examined by pooling all similar groups and comparing the availability of surplus energy between different pooled groups using ANOVA to test the hypothesis that the relative concentration of TAG does not differ between groups with different fatty acid profiles.

For all linear models, relative fatty acid concentrations will be normalized by dividing the sum of all fatty acid concentrations into the concentration observed for each fatty acid, and surplus energy will be estimated by calculating the proportion of total lipid that is represented by TAG. All assumptions of homogeneity of variances and normality made by the general linear model will be examined for the data prior to testing, and appropriate transformations will be made. Estimates of the power of this analysis are currently unavailable since this study is designed to provide variance estimates for future analyses

The fatty acid profiles of the zooplankton will be compared to the profiles obtained from fish collected in the same locations by a randomization procedure. An empirical distribution of

differences between zooplankton samples collected from the same portion of PWS will be generated by calculating the sum of the squared differences between each of the relative fatty acid concentrations of two zooplankton samples. With 16 samples, a total of 128 unique differences can be observed in this manner. The difference between each fish and the mean fatty acid profile for the zooplankton will be calculated as the sum of the squared differences for each of their fatty acids, and compared to the empirically derived distribution of differences. A fish will be considered different if the difference between it and the mean fatty acid composition is greater than 95% of the randomly selected differences in the empirical distribution. We recognize that significant differences exist between the composition of the prey field and the stomach contents of herring and sandlance, thus the absence of differences under this analysis coupled with detectable differences in prey and predator fatty acid profiles over longer distances provides a robust basis for examining trophic relationships between zooplankton and their predators.

Consequences of Low and High Fat Diets for Fatty Acid Profiles and TAG Availability in Sea Lions (Objectives 3 and 4)

The sea lion feeding study proposed here supports the proposed "*Pinniped Muscle Response To Diet*" project designed to take place at the Sea Life Center in Seward, Alaska and depends on that project for sea lion feeding, sample collection and shipping. Sea lions diets will be alternated between high (herring) and low fat (pollock) fish on 15 week cycle. Sea lions and their food will be sampled for lipid analysis once every 5 weeks for three cycles. Full depth blubber cores will be drawn from near the pelvic region of three sea lions using sterile biopsy punches. The resulting core will be placed in labeled airtight jars, and immediately frozen at -20°C. At the same time, a 50 ml blood sample will be withdrawn by syringe, placed in a heparinized tube, centrifuged in salt solutions to isolate the fraction containing chylomicrons which will be decanted and frozen. Food samples will be collected weekly, so that a total of 15 representative samples will be collected during each cycle. The 50 g food samples will be placed into separate airtight containers and frozen immediately. Frozen sea lion tissues and food will be maintained at -20°C, and shipped frozen to Auke Bay for extraction and further analysis.

Samples received from the Sea Life Center will be extracted within 200 days of collection. Blubber cores will be divided into three sections, and each section will be analyzed for lipid class composition, and the concentrations of all the fatty acids in the neutral lipid component will be measured following the analytical procedures described below. Food samples will be homogenized, and the concentrations of all the fatty acids in the entire sample will be measured as well as the lipid class composition.

The fatty acid profiles observed in sea lion food will be compared to the profiles obtained in each of the blubber sections and blood through a randomization procedure. Fatty acid concentrations will be transformed into relative concentrations by dividing the concentration of each fatty acid by the sum of all the fatty acid concentrations. Differences between the fatty acid profiles of a sea lion tissue and their food will be examined by calculating sum of the squared differences between the tissue and food for each of the relative concentrations of fatty acids. This sum will be

compared to an empirical distribution of differences generated by comparing two food observations of the same type and measuring the sum of the squared differences in their relative concentrations of fatty acids for each food type. A distribution for both the low and high fat foods will be generated, by calculating the 125 unique differences that will be possible out of each type's 15 observations. If the sum of the squared differences between the sea lion tissue and the food is larger than 95% of the differences in the empirical distribution then the profiles will be considered different. This analysis should be considered conservative with respect to identifying similarities in fatty acid profiles since it assumes that the relative frequency of fatty acids in the food is not modified by the sea lions.

Lipid Class/Fatty Acid Analysis

Samples will be extracted by methods developed by Folch (1957) and modified by Iverson (1988). Lipid classification will employ high performance liquid chromatography (HPLC) and evaporative light scattering detection (ELSD) equipped with a stream splitter and an automated integration system. The lipid classes will be separated on a silica based HPLC column; as they elute from the column, each lipid class will be split with one portion being directed to the detector and the other portion being collected for fatty acid (FA) analysis. The portion going to the detector will be integrated and the chromatographic data for each lipid class will be quantified by standard calibration curves established by analyzing standards with lipid compositions similar to the sample.

After separation from the other lipid classes the neutral lipid portion of the sample extracts will undergo acid catalyzed transesterification as outlined in Christie (1982). The resulting fatty acid methyl esters (FAME) will be determined using a gas chromatograph coupled with a mass selective detector (MSD). The FAME will be identified by comparison of the chromatographic peaks with those of known laboratory standards. Peaks not identified by direct comparison to standards will be identified from the fragmentation pattern resolved by the MSD. Fatty acids will be reported as a percentage of the total amount of FA and named according to IUPAC nomenclature.

These methods will give results directly comparable to that of the conventional methods using TLC/Iatroscan for lipid class determination and gas chromatography-flame ionization detection (GC-FID) for FAME analysis. The ELSD will allow for simultaneous detection and separation of lipid classes without developing rods or TLC plates and without extracting lipids from the TLC media for FA analysis. Likewise, analysis of FAME mixtures by MSD will forego the need for silver nitrate augmentation to identify of peaks that are not components of standard mixtures. Since each compound has a unique fragmentation pattern the identity of unknown peaks can be determined from the mass spectral data.

## C. Cooperating Agencies, Contracts, and Other Agency Assistance

The experiments described in this proposal are designed to 1) initiate development of these techniques for examining broad scale trophic relationships 2) supplement other Trustee Projects

and 3) complement ongoing Stellar sea lion diet studies initiated under the NMFS *Stellar Sea Lion Recovery Plan*. The forage fish experiment depends on the sampling protocol of APEX study 97163A. Using the this study plan, we can obtain samples for processing at the beginning of FY 98. APEX investigators will be responsible for collecting, labeling and storing samples until they return to Auke Bay. APEX 97163A will benefit from our analysis by relating our measures of dietary differences and their energetic consequences to their coarser indices of nutritional condition. The examination of the spatial scale of variability in herring fatty acid profiles will be of direct benefit to Restoration Study 97064, which examines the fatty acid profiles of harbor seals. The sea lion feeding study is designed to complement a project proposed for FY 98 entitled *"Pinniped Muscle Response To Diet"*. In this project investigators will examine the effect of the different diets on mitochondria production in sea lions. The energetic information provided by our analysis of lipid class composition will directly benefit their work. Information on the fatty acid composition of sea lions obtained under our project coupled with data provided by Restoration Study 97064 provide a basis for developing this technique with Killer Whales, as well as provide a basis for extending the stable isotope based research of upper trophic level changes proposed by the National Marine Mammal Lab to be funded by GLOBEC.

## SCHEDULE

### A. Measurable Project Tasks for FY 98 (October 1, 1997 - September 30, 1998)

| | |
|---|---|
| Oct 1997 | Purchase Evaporative Light Scattering Detector |
| Jan 1998 | Begin analysis of herring, sandlance, zooplankton |
| Jul 1998 | Complete analysis of herring, sandlance, zooplankton |
| Oct 1998 | Begin Sea Lion Feeding Project |

### B. Project Milestones and Endpoints

FY98

| | |
|---|---|
| Oct 1997 | Purchase ELSD |
| Jan 1998 | Begin analyzing herring, sandlance and zooplankton samples. |
| July 1998 | Analysis of herring, sandlance, and zooplankton complete |

FY99

| | |
|---|---|
| Oct. 1998 | Begin sampling of sea lions (time dependent on Sea Life Center opening) |
| Jan. 1999 | Report for forage fish experiment completed. |
| Aug 1999 | Complete sampling of sea lions |

FY00

| | |
|---|---|
| Jan 2000 | Analysis of sea lion samples complete |
| Oct 2000 | Report on sea lion experiment completed, Final Report submitted |

## C. Completion Date

This project will occur in FY98, and FY99, FY00. Synthesis of herring, sandlance, and zooplankton data will be complete in the middle of FY99. Synthesis of sea lion data will be complete at the end of FY00.

## PUBLICATIONS AND REPORTS

April 1998: Annual Report containing update on sample processing for the forage fish experiment.

Jan 1999 Submit forage fish report to journal:

*Heintz, R , M. Larsen, S. D. Rice, and APEX investigator. 1999. Spatial Variation of Fatty Acid Profiles and Lipid Class Compositions in Herring, Sandlance and Their Prey in Prince William Sound, Alaska. Journal uncertain.*

April 1999: Annual Report containing final data on the forage fish experiment, update on sea lion experiment.

April 2000: Annual Report containing update on sea lion sample processing.

Oct. 2000: Final report submitted for of this proposal. Submit final sea lion report to journal:

*Larsen, M, R. Heintz, S. D. Rice, R. Merrick and D. Duffy. 2001. Fatty Acid Deposition in the Lipids of Captive Sea Lions. Journal uncertain.*

## PROFESSIONAL CONFERENCES

Report on forage fish results at National Meeting of the American Fisheries Society in September 1998.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

NOAA NMFS has statutory stewardship for all living marine resources; however, if the oil spill had not occurred NOAA would not be conducting this project. NOAA NMFS proposes to make a significant contribution (as stated in the proposed budget) to the operation of this project, making it truly cooperative.

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

This section is not applicable to this project.

## PROPOSED PRINCIPAL INVESTIGATOR

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Revision 6/97
Approved TC 8-6-97

# 1997 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1996 - September 30, 1997

| Budget Category: | | Proposed FFY 1998 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | | $61.3 | | | | | | |
| Travel | | $4.1 | | | | | | |
| Contractual | | $0.0 | | | | | | |
| Commodities | | $20.0 | | | | | | |
| Equipment | | $16.0 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | | $101.4 | Estimated FFY 1999 | Estimated FFY 2000 | Estimated FFY 2001 | Estimated FFY 2002 | Estimated FFY 2003 | |
| General Administration | | $9.2 | | | | | | |
| Project Total | | $110.6 | $92.6 | $35.3 | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.9 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

1998

98347 Fatty Acid & Lipid Analysis

NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

## 1997 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1996 - September 30, 1997

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FFY 1998 |
| R Heintz | Fisheries Research Biologist | 11/5 | 1.5 | 6.3 | | 9.5 |
| M Larsen | Research Chemist | 11/6 | 2.0 | 5.6 | | 11.2 |
| L Holland | Research Chemist | 11/6 | 2.0 | 5.6 | | 11.2 |
| J Lunasin | Research Chemist | 9 | 5.0 | 4.8 | | 24.0 |
| S Rice | Physiologist | 14 | 0.5 | 10.8 | | 5.4 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 11.0 | 33.1 | 0.0 | |
| | | | | | Personnel Total | $61.3 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FFY1998 |
| Anchorage, Workshop, 1 | 0.4 | 1 | 4 | 0.2 | 1.2 |
| Miscellaneous (Car rental, telephone chgs, POV mileage, etc.) | | | | | 0.3 |
| | | | | | 0.0 |
| National American Fisheries Society Meeting | 1.6 | 1 | 4 | 0.2 | 2.4 |
| Miscellaneous (Car rental, telephone chgs, POV mileage, etc.) | | | | | 0.2 |
| | | | | | 0.0 |
| | | | | Travel Total | $4.1 |

Project Number:
Project Title: Fatty Acid and Lipid Class Analysis for Estimating Diet Compostion and Quality in Sea Lions and their Prey
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Personnel
& Travel
DETAIL

Prepared:



6/26/97

# 1997 EXXON VALDEZ TRUST[illegible]UNCIL PROJECT BUDGET
October 1, 1996 - September 30, 1997

| Contractual Costs: | Proposed FFY 1998 |
|---|---|
| Description | |
| | |
| When a non-trustee orga **Contractual Total** | $0.0 |

| Commodities Costs: | Proposed FFY 1998 |
|---|---|
| Description | |
| Sample Analysis: standards, solvents, reagents, glassware, columns | 20.0 |
| **Commodities Total** | $20.0 |

1998

Project Number:
Project Title: Fatty Acid and Lipid Class Analysis for Estimating Diet Composition and Qualaity in Sea Lions and Their Prey
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Contractual & Commodities DETAIL

Prepared:



6/26/97

| New Equipment Purchases: | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FFY 1998 |
| Evaporative Light Scattering Detector | 1 | 16.0 | 16.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $16.0 |

| Existing Equipment Usage: | Number | Inventory |
|---|---|---|
| Description | of Units | Agency |
| High Performance Liquid Chromatograph | 1 | NMFS |
| Gas Chromatograph/Mass Selective Detector | 1 | NMFS |

Project Number:
Project Title: Fatty Acid and Lipid Class Analysis for Estimating Diet Composition and Quality in Sea Lions and Their Prey
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Equipment
DETAIL

Revision 6-24-97
approved RC 8-6-97

# Responses of River Otters to Oil Contamination: A Controlled Study of Biological Stress Markers

| | |
|---|---|
| Project Number: | 98348 |
| Restoration Category: | Research |
| Proposer: | M. Ben-David, T. Bowyer, L. Duffy/UAF |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | Yes |
| New or Continued: | New |
| Duration: | 1st yr.<br>2 yr. project |
| Cost FY 98: | $245.4 |
| Cost FY 99: | $176.6 |
| Cost FY 2000: | $0.0 |
| Cost FY 01: | $0.0 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Seward |
| Injured Resource/Service: | River otter |


## ABSTRACT

This project will explore the effects of oil contamination on physiological and behavioral responses in river otters experimentally. Fifteen captive otters will be exposed to two levels of oil contamination under controlled conditions in captivity. Samples of blood, tissues, and feces will be collected for analysis of biomarkers and immunological examinations.

## INTRODUCTION

This proposal originates from the need to better understand the effects of contamination by crude oil on biological stress markers in river otters (*Lutra canadensis*). Previous studies demonstrated elevated levels of biological stress markers (bioindicators) in river otters from oiled areas compared with those from nonoiled areas throughout Prince William Sound, Alaska, shortly following the *Exxon Valdez Oil Spill* (*EVOS*). In addition, elevated values of bioindicators have been documented in river otters as part of the *EVOS* - Nearshore Vertebrate Predator Project (NVP) 7 years after the spill.

Although the data collected to date strongly indicate a correlation between oil contamination and physiological stress in river otters, this circumstantial evidence requires verification through controlled experiments as identified by the *EVOS* Trustees Council review process (1997). Also, it is difficult to assess from the evidence collected to date whether the physiological stress is a direct result of oiling or a secondary response to food limitation (Fig. 1). The documented injury to the prey base of river otters, however, is not sufficient to explain the observed pattern of physiological stress.

In this study, we propose to investigate the effects of exposure to oil on physiology of river otters under controlled conditions, and hypothesize that exposure to oil will result in elevated levels of bioindicators in river otters.

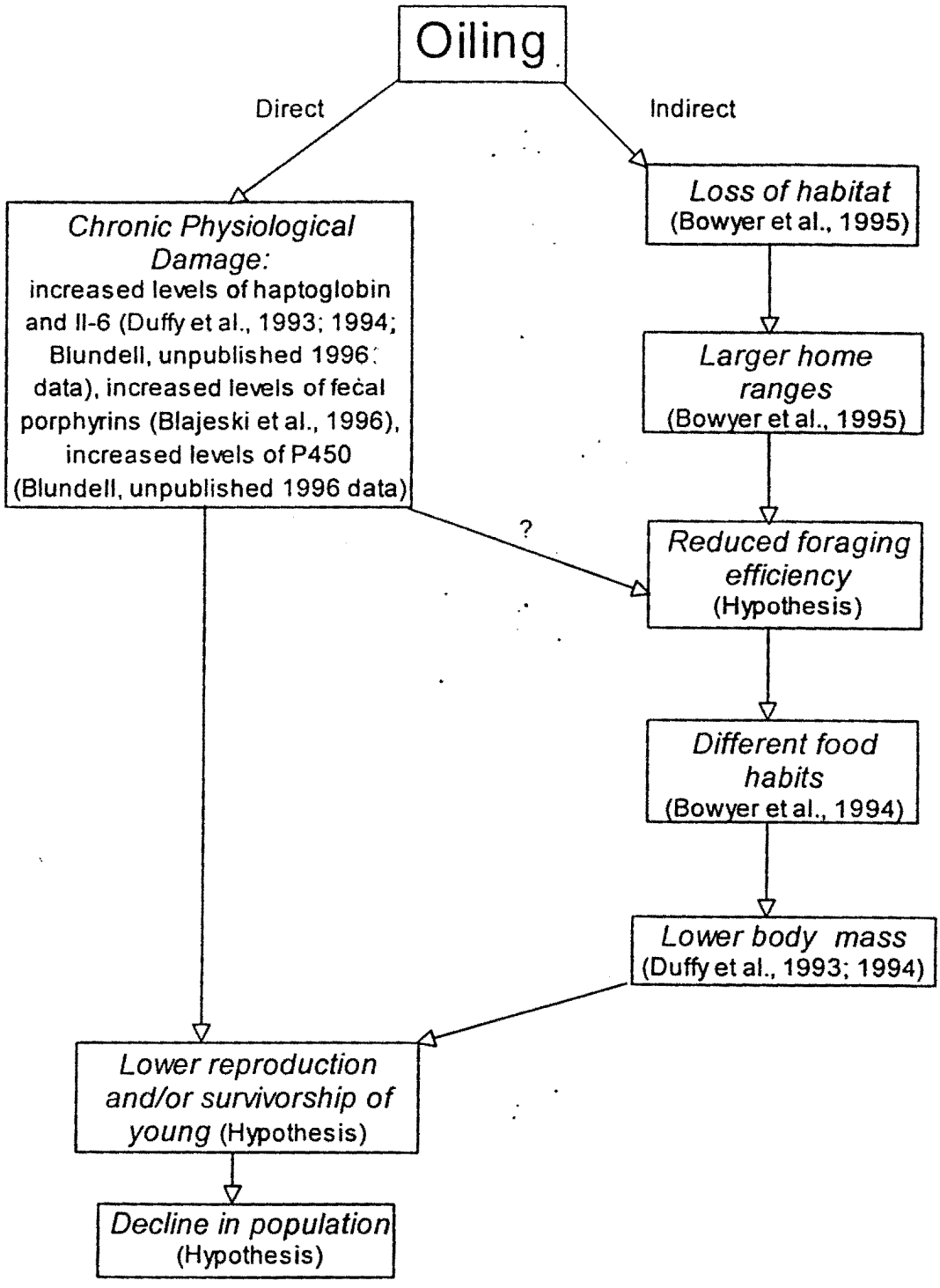


Fig. 1 - Possible pathways for the effect of oiling on river otters in Prince William Sound, Alaska

## Background

*General*

Investigations in Prince William Sound following the *Exxon Valdez* oil spill revealed that river otters (*Lutra canadensis*) on oiled shores had lower body mass and elevated levels of bioindicators, than did otters living on nonoiled shores (Blajeski et al., 1996; Duffy et al. 1993; 1994a; 1994b; 1996). In addition, otters from oiled areas selected different habitat characters, had larger home ranges, and less diverse diets than those in nonoiled areas (Bowyer et al. 1994; Bowyer et al. 1995). These observed differences between river otters from oiled shores and those from nonoiled areas strongly suggest that oil contamination had an effect on physiological and behavioral processes in otters. Moreover, these effects have a potential to become chronic and may impede recovery of populations of river otter as hydrocarbon exposure continues. Between 8-16% of the 10.8 million gallons of crude oil spilled by the *T/V Exxon Valdez* remains buried in marine sediments (Wolfe et al., 1994). Such oil is not subject to degradation by marine organisms and remains in a form that is toxic to many vertebrates (Braddock et al., 1996). Moreover, microbial analyses indicates that oil in sediments along oiled shorelines is still several orders of magnitude more common than in unoiled areas (Braddock et al., 1996), suggesting oil may still be available for biological transport from benthic invertebrates through the food chain.

*Biomarkers*

Studies initiated following the *EVOS* suggest that several mammalian and avian predators display physiological stress related to oil toxicity. Sea otters from oiled regions had greater antigenic stimulation than animals from unoiled areas (Rebar et al., 1994). Pigeon guillemots had elevated levels of haptoglobins and blood proteins in specific locations and years, although dosing experiments in the field failed to demonstrate the connection between oiling and those parameters (Prichard et al., in press). More specifically, river otters live captured in oiled areas had higher haptoglobin, Interleukin - 6 (Il-6), and fecal porphyrin levels than otters from nonoiled regions post spill (Blajeski et al., 1996; Duffy et al., 1994; 1994). In addition, river otters showed elevated haptoglobin and P450 values in 1996 (G. M. Blundell, pers. comm.). Similar changes in plasma proteins, abnormalities in white blood cells (leukocytes), reduction in the number of red blood cells (erythrocytes), and electrolyte imbalance, were observed in mink (*Mustela vison*) and polar bears (*Ursus maritimus*) following exposure to hydrocarbons (Mohn and Nordstoga, 1975; Oristsland et al., 1981).

Cytochrome P450 are a group of enzymes that metabolize a wide variety of xenobiotic compounds. P450-1A is specifically induced by planar aromatic or chlorinated hydrocarbons, and thus its presence serves as a bioindicator of hydrocarbon exposure. Haptoglobin and Il-6 indicate increase liver activity in synthesizing acute-phase proteins in response to tissue injury (Duffy et al., 1993; 1994). Porphyrins are tetrapyrrolic pigments that are involved in biosynthesis of the heam molecule. Chemical-induced

changes in patterns of porphyrins have been observed in several avian species following an exposure to aromatic hydrocarbons (Miranda et al., 1987) Other physiological responses such as those of the immune system have been used recently in the *EVOS* - NVP project as assays to toxic damage of oil.

Although the data collected to date strongly indicate a relationship between oil contamination and physiological stress in river otters, this circumstantial evidence requires verification through controlled experiments. The *EVOS* Trustees Council review process (1997) identified the need for such controlled-experiments: "....For river otters captive laboratory exposures to petroleum ...is needed to solidify the cause for P450-induced individuals in western PWS.....captive experiments that examine the relationship between oil dose and biochemical responses in the species where such responses appear to be related to spill effects should be done.....To obtain a better basis for interpretation of the field haptoglobin and fecal porphyrin data, controlled oil exposures of river otters are highly recommended."

*Foraging success*

Diet of river otters from oiled shores was significantly different than that of otters from unoiled areas (Bowyer et al., 1994). Surveys of intertidal organisms in Prince William Sound, suggested that species composition and biomass of subtidal fishes did not differ between oiled and nonoiled areas (Thomas Dean, Pers. Comm.). In addition, diets of otters along oiled shores were more similar to the species composition of subtidal fish than that of otters from nonoiled shores (Bowyer et al. 1994; Thomas Dean, Pers. Comm.) suggesting that otters on oiled shores differed in their foraging strategies from otters on nonoiled areas.

Kruuk et al. (1990) demonstrated that foraging success of European river otters (*Lutra lutra*) in marine environments in Shetland, was determined largely by behavior of both prey and predators. Foraging behavior of semi-aquatic mammals such as river otters will be partially determined by their diving ability. For mink (*Mustela vison*), several studies have shown that the relatively small surface of their feet, their anterior propulsion, and their low storage capacity for $O_2$ make them an inefficient swimmer compared with other diving mammals (Ben-David et al., 1996; Dunstone and O'Connor 1979*a*; 1979*b*; Stephenson et al. 1988; Williams 1983; 1989; Williams and Kooyman 1985). Although river otters have a higher surface-area of feet, higher storage capacity for $O_2$, and better propulsion capabilities (Fish, 1994; Tarasoff et al., 1972), these limitation on swimming and diving efficiency could affect the duration and depth of dives especially in sea water, which has higher density and viscosity than does fresh water (Vogel 1981). Exposure to oil, associated chronic physiological stress, and reduction in numbers of red blood cells (i.e. lowered $O_2$ storage capacity; Oritsland et al., 1981) could have an affect on the diving ability of otters (see Fig. 1). The diet of otters in oiled areas in PWS was largely composed of sessile subtidal fish that are easier to catch. Therefore, the physiological

stress imposed on oiled otters may have resulted in the observed differences in diet between otters in oiled and nonoiled areas (Bowyer et al. 1994).

Diving behavior, energetics, foraging success and recovery times of European river otter have been studied extensively in captivity (Kruuk, 1995). Based on these observations the relationships between foraging efficiency and prey abundance was modeled for the European otters (Kruuk, 1995). Repeating these experiments on river otters in relation to oil contamination will provide useful information on the mechanisms by which exposure to oil affects river otters.

River otters in Prince William Sound frequently occur and forage in social groups (Rock et al., 1994). Group living could improve foraging success of predators if hunting is coordinated among members of the group (Kruuk, 1975). Although foraging behavior of wild otters is poorly documented, it is possible that foraging efficiency changes with group size. The controlled experiment described below will provide a good opportunity to investigate the hypothesis that foraging efficiency of otters increases with group size. The observed differences in diets of otters between oiled and nonoiled areas coupled with the observation that many otters foraged in large groups (Testa et al., 1994; Ben-David pers. obs.) suggest that exposure to oil may affect foraging of groups of otters. Therefore, we intend to explore the effects of oil contamination on groups of foraging otters and address the hypothesis that exposure to oil affects foraging behavior of groups of otters.

## NEED FOR THE PROJECT

### A. Statement of Problem

The 1997 review process of the NVP Project funded by the *EVOS* Trustees Council identified the need to verify the effects of oil contamination on physiological stress responses in river otters. Data collected in summer 1996 revealed that coastal river otters in the western Prince William Sound are still exposed to oil contamination (P450) and show high levels of haptoglobins. These results may indicate that restoration of river otter populations may be impeded by the continued exposure to hydrocarbons. Nonetheless, as long as the connection between exposure to oil and bioindicators is not demonstrated under controlled conditions, the interpretation of the results is limited because of the correlational nature of these data.

In addition, it is difficult to assess from the evidence collected to date whether the physiological stress is a direct result of oiling or a secondary response to food limitation (Fig. 1). The documented injury to the prey base of river otters, however, is not sufficient to explain the observed physiological stress. This generated the hypothesis that exposure to oil may have an affect on the diving ability of otters and therefore their foraging success.

This study will investigate the effects of exposure to oil on bioindicator levels in river otter tissues as well as the effect of such exposure on foraging behavior and success of individual and groups of river otters under controlled captive conditions. Using the behavioral data on foraging behavior, capture success, and the energetic models developed to date for diving semi-aquatic mammals (Kruuk, 1995), we intend to evaluate the differences in foraging efficiency of river otters exposed to oiling.

### B. Rationale/Link to Restoration

Effective implementation of the *EVOS* Trustee 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. The existing evidence of chronic physiological stress in a wide variety of nearshore vertebrate predators (see NVP project) requires verification under controlled experiments, before the mechanisms that constraint recovery can be understood.

### C. Location

River otters will be captured in the western PWS and transported via air to the Alaska Sealife Center in Seward, where the controlled experiments will be conducted.

## COMMUNITY INVOLVEMENT

This project will involve intensive data collection both in the Sealife Center as well as in the different laboratories. We will recruit high school and undergraduate students to assist in the data collection. Preference will be given to students from local communities. In addition, supply of live-fish prey will be crucial for the behavioral experiments. It is our intention to contract local fishermen to provide us with these prey.
The captive river otters in the Sealife Center will be available for public viewing and education. We will participate in the development of the educational materials associated with the river otter display. We will also welcome opportunities to interact with local communities to present and discuss our findings.

## PROJECT DESIGN

### A. Objectives

The objective of this study is to document the effects of exposure to oil on physiology and behavior of river otters under controlled conditions. We will address the following hypotheses:

1. Exposure to oil will result in elevated levels of bioindicators in river otters.
2. Exposure to oil will affect foraging behavior and foraging success of river otters.

## B. Methods

### General

Fifteen wild male river otters will be live captured from the wild in unoiled areas in western PWS using No. 11 Sleepy Creek leg-hold traps (Blundell et al., in review) under permit from the Alaska Department of Fish and Game (requested 4/9/97). Traps will be placed on trails at latrine sites and monitored by means of trap transmitters (Telonics, Mesa, Arizona, USA) that signal when a trap has been sprung. Processing of otters will begin within 1 - 2 hours. Otters will be anesthetized with Telazol (9mg/kg; A. H. Robins, Richmond, Virginia, USA) administered using Telinject darts and a blowgun.

Once anesthetized, otters will be weighed (to the nearest 0.1 kg), and measured (to the nearest 1 mm). These measurements will include body length, tail length, and total length; total skull length and width of zygomatic arch; length from hock to toe of the right hind foot: canine length and diameter, and distance between canines. Age of otters will be determined by removing an upper premolar 1 for cementum annuli aging. We will insert a PIT tag under the skin between the scapulae of each individual to allow for individual identification. In addition, colored tags in unique combinations will be inserted in the animals ears to allow for visual identification.

The fifteen wild-caught male river otters will be transferred under sedation via air to the Alaska Sealife Center in Seward, Alaska. Otters will be housed in two large enclosures with a large saltwater pool and a small freshwater pool. Each otter will be provided with an individual solid sleeping box. Otters will be fed live fish on a daily basis in the large saltwater pool, and diet will be supplemented with prepared food mixture (mink chow), vitamins, and minerals (Robbins, 1993).

After an acclimation period of 1 month, otters will be randomly assigned to five experimental groups of three individuals each:

Group 1 - control
Group 2 - single exposure to low levels of oil (1000 ppm)
Group 3 - triple exposure to low levels of oil at 3 week interval
Group 4 - single exposure to high levels of oil (10,000 ppm)
Group 5 - triple exposure to high levels of oil at 3 week interval

Prior to the exposure to oil a series of tissue sampling and behavioral observations on foraging behavior and success will be conducted on each individual otter. The day of sampling (tissues and behavior) prior to oil administration will be termed day 0 of the experiments for each otter (the actual date of this day may differ slightly between individuals and will depend on the number of individuals personnel will be able to handle in one day). Table 1 describes the schedule of oil administration and sampling.

Oil will be administered to otters mixed with prepared food (mink chow). Weathered (comparable to 2 weeks weathering) Prudhoe Bay Crude oil will be dissolved in salmon oil and than mixed with the food.

Table 1. Schedule of experiments for captive river otters to examine the effects of crude oil, Seward Sealife Center.

| Treatment | Day | Group 1 control | Group 2 low | Group 3 low | Group 4 high | Group 5 high |
|---|---|---|---|---|---|---|
| Behavioral observations | 0 | x | x | x | x | x |
| Tissue sampling | 1 | x | x | x | x | x |
| **Oil administration** | 2 | | x | x | x | x |
| Behavioral observations | 8 | x | x | x | x | x |
| Tissue samples | 9 | x | x | x | x | x |
| **Oil administration** | 22 | | | x | | x |
| Behavioral observations | 29 | x | x | x | x | x |
| Tissue samples | 30 | x | x | x | x | x |
| **Oil administration** | 43 | | | x | | x |
| Behavioral observations | 50 | x | x | x | x | x |
| Tissue samples | 51 | x | x | x | x | x |
| Behavioral observations | 150 | x | x | x | x | x |
| Tissue samples | 151 | x | x | x | x | x |

Following completion of the experiments river otters will be released back into the wild at the site of their original capture. These animals will be implanted with radiotransmitters following the surgical protocol described below and monitored using aerial telemetry for the next 6 months.

Otters will be anaesthetized to a surgical plane with a combination of Ketamine Hydrochloride (100 mg/ml, Ketaset, Aveco Co., Fort Dodge, Iowa, 50501, USA) at a dose of 10 mg/kg, and Midazolam Hydrochloride (5 mg/ml, Versed, Hoffman-LaRoche, Nutley, New Jersey 07110, USA) at a dose of 0.25 mg/kg mixed in the same syringe (Spelman et al., 1993). The surgery site will be shaved and surgically scrubbed with Nolvasan soap and a final iodine prep. Once the site is prepared and prior to making the incision, the otter will be checked to ascertain depth of anesthesia and proper analgesia. The surgeries will be performed by a veterinary technician with specialized training in the procedure, using methods outlined in Testa et al. (1994). All surgeries will be done adhering to sterile technique. We will use a side entry, posterior to the last rib to introduce a hermetically sealed radiotransmitter (IMP/400/L; Telonics, Mesa, Arizona) into the peritoneal cavity. Each muscle layer will be closed separately with simple interrupted sutures, the skin will be closed with a continuous subcuticular suture line to prevent the otter from accessing any sutures. As a final precaution, the skin incision will be sealed with surgical glue. We have performed this surgery successfully many times on wild river otters.

Animals that will suffer minor but noticeable damage due to oil administration that will threaten their survival in the wild will be kept at the Sealife Center for public viewing and education. In instances where oil damage will cause pain and major suffering, animals will be humanely euthanized using inter vinous injection of 0.5cc/kg body mass. Any carcasses will be used for full pathological screening. All methods used in this research will be approved by an independent Animal Care and Use Committee at the University of Alaska Fairbanks, Fairbanks, Alaska (proposal submitted 4/9/97), in compliance with policies recommended by the National Institutes of Health (NIH), the National Science Foundation (NSF), and the Scientists Center for Animal Welfare (SCAW).

**Tissue sampling**

Collection of tissue samples will follow the same operating protocol as used in the NVP project to assure that results will be comparable. The assays performed on the tissue samples will include: haptoglobin, Il-6, P450-1A (in epithelial cells and WBC), CBC, WBC, and serum chemistry, lymphocyte blastogenesis, serum protein electrophoresis, immunoglubolin quantitation, delayed type hypersensitivity reactions, DNA adduct analysis.

A total of 22 milliliters of blood will be drawn from the jugular vein of each otter with care to keep samples sterile. Ten milliliters will be preserved with heparin (40u/ml or 0.4ml/10ml of blood) and stored in a red top vacutainer. An additional 2 ml will be preserved with EDTA (purple top vacutainer), and 10 ml of blood will be collected in a red top vacutainer and allowed to clot. Two blood smears will be made for each river otter on site, at the time of blood draw. A tissue sample from the medial surface of the left front limb in the triceps area will be collected from each river otter using a 3mm disposable skin biopsy punch. The specimen will be preserved in 10% neutral buffered formalin immediately after collection.

In the laboratory, red-top tubes will be centrifuged at low speed (800 x g,) for 20 minutes. Serum will be drawn from the clot of the centrifuged sample and frozen separately. All serum samples, and the clot, will be frozen within 12 hours of obtaining the samples. The plasma will be drawn off of the heparinized sample with care so as not to disturb the buffy-coat layer. One milliliter of the plasma will be mixed with 0.2 ml of DMSO (tissue culture grade) and placed on ice. The buffy-coat will be removed from the erythrocyte layer and placed in a snap top tube along with 1 ml of plasma. The plasma/DMSO will then be added slowly (one drop at a time) to the mixture. The mixture will be aliquoted into two cryovials (approx. 1 ml each), placed into a prechilled Nalgene freezing unit and placed into the freezer for 12 hours. The buffy-coat samples will be transferred to a liquid nitrogen dewar for storage and eventual transport to the Purdue University laboratory. Any remaining plasma will be frozen. EDTA samples and one blood smear from each otter will be flown to a laboratory in Anchorage (Quest Lab c/o Laurie Rubin, 562-2551) for a complete blood count within 72 hours of the blood draw. All serum and

plasma will stay frozen and sent, periodically, to Fairbanks for analysis. Serum samples will be sent to Quest Lab for Serum Chemistry Panels and other tests as needed.

**Assays Biological Stress Markers and Immunology**

*Haptoglobins*

Haptoglobins (Hp) are alpha$_2$ glycoproteins that stoichiometrically bind free hemoglobin (Hb) in a haptoglobin-hemoglobin complex. Excess hemoglobin will be added to the serum sample in a 1 part of a 10% hemoglobin suspension to 20 parts of undiluted serum, and allowed to mix for 5 min. Two microliters of the sample mixture will then be electrophoresed on agarose gels at 100 volts for 1 hr. After fixing the protein complex with 7.5% trichloroacetic acid, gels will be stained for hemoglobin using o-dianisidine, as described by the manufacturer. The Hp-Hb complex, which migrates in a different region from hemoglobin, is quantitated by densitometry and results are expressed as mg of hemoglobin binding capacity per 100 ml of serum as described by the manufacturer.

*Interleukin - 6*

Samples received from the captive otters will be analyzed for IL-6 levels using an immunochemical assay . Samples, run in duplicate, will be added to a microliter plate coated with a monoclonal antibody for IL-6. After washing away any unbound proteins, an enzyme-linked polyclonal antibody for IL-6 will be added to the wells and incubated to allow for any IL-6 binding. After a final wash, a substrate solution will be added to the wells. After color develops, sample concentrations will be determined from a standard curve. IL-1ß will be measured similarly.

*Cytochrome P450 assays*

Two approaches will be taken to evaluate cytochrome P450 levels:

1) Immunohistochemistry: The induction of cytochrome P4501A (CYP1A) in tissues of the river otters will be evaluated by immunohistochemistry. Candidate tissues to be used include skin punches. Tissue samples will be preserved in 10% neutral buffered formalin immediately after collection and shipped to Woods Hole Oceanographic Institute for analysis (by Dr. J. Stegman).

Analytical SDS-PAGE will be done using a modified procedure of Laemmli[31]. The test and control media will be removed from the 12 well plate, and each well will be rinsed twice with 2 ml cold wash buffer (62.5 mM Tris-HCl, pH 6.8). Sample buffer (2.35% [w/v] SDS, 10% [v/v] glycerol, 5% [v/v] ß-mercaptoethanol, and 62.5 mM Tris-HCl; pH 6.8) will be added to each well (200 µl per well) to solubilize the cells. Cell lysates will be collected from individual wells and stored at -20°C. Test samples will be

heated to 90°C for several minutes and equal volumes loaded in 9 or 10% (w/v) acrylamide: 0.27% (w/v) bis-acrylamide slab gels (approximately 12 x 16 cm, 0.75 mm thick) and run at 20 mA constant current per gel for approximately 4 h to resolve individual bands.

The gels will be fixed and stained using a Sigma Chemical Co. AG-25 silver staining kit procedure. Analytical gels will be prepared as above and electrobloted onto nitrocellulose membranes using 25mM Trisma base, 192 mM glycine, and 20% (v/v) methanol for 3 h at 100 V. The membranes will be then blocked in 5% nonfat dried milk in CMF-PBS, washed four times in CMF-PBS, and incubated with antibody to hsp 70 and 141 which recognizes a conserved epitope present in most members of these families. The blots will be washed as before and incubated with an HRP-conjugated goat antirat IgG antibody (Sigma, A-9037) as the secondary antibody. For the color development, the blot will be washed as before and stained using 3,3'-diaminobenzidine tetrahydrochloride (DAB) as the HRP substrate (Sigma Fast® DABkit D-4418).

2) Quantitative RT-PCR to measure cytochrome P450: The purpose of this approach is to use an alternate method (quantitative polymerase chain reaction) to measure cytochrome P450 expression in peripheral blood lymphocytes. The lymphocytes will be isolated from blood samples drawn from animals captured from oiled and non-oiled areas. The method to be used will be adapted from Vanden Heuvel et al. (1993). Total RNA will be extracted from isolated peripheral blood lymphocytes and a reverse transcriptase-polymerase chain reaction (RT-PCR) assay will be used to quantify cytochrome P450 levels. Advantages of this technique are: (1) the use of peripheral blood samples for analysis; (2) the small sample size required for detection and (3) potentially increased sensitivity as compared to other methods (by Dr. P. Snyder).

*Hematology and serum chemistry*

For CBC (complete blood cell counts), WBC (white blood cell counts), and serum chemistry samples will be submitted to commercial clinical laboratories. The serum samples from the captive river otters will be batch tested at Purdue University for serum electrophoresis (SEP) and immunoglobulin quantitation using standard methodologies. Serum protein electrophoresis offers information on relative protein distribution and allows for the calculation of absolute values (Melvin 1987). Many disease states may alter the electrophoretic pattern (Turnwald and Barta 1989). Acute phase, complement, immunoglobulin and coagulation proteins can all be assayed using SEP.

*Immune function assays*

A total of 10 ml of blood collected with 40u of preservative-free heparin/ml as the anticoagulant will be used to isolate buffy coat leukocytes. Blood samples will be processed using a technique modified from Truax et. al. (1993) on cryopreservation of buffy coat cells, stored in liquid nitrogen, and shipped to Purdue University. For analysis, frozen cells will be thawed rapidly in a 37°C water bath and immediately placed on ice.

The sample will then be transferred to a 15 ml centrifuge tube and diluted to 10 ml with Hank's balanced salt solution (HBSS) containing 40u of heparin/ml. The sample will then be layered over 4 ml of a ficoll gradient and centrifuged at 1600 x g for 30 minutes. The cells at the interface will be collected and washed 3 times in HBSS. Following the final wash the cells will be resuspended in RPMI 1640 medium supplemented with 10% (v/v) fetal clone, 2 mM L-glutamine, 25 mM 2-mercaptoethanol and antibiotics. Enumeration and viability will be assessed using trypan blue dye-exclusion. Lymphocyte proliferation assays will be performed using the mitogens PHA, Con A and PWM in 5 day cultures. All assays will be done in triplicate. Proliferation will be assayed by adding tritiated thymidine to the cultures at 16 hours prior to harvesting. Results will be recorded as counts per minute (cpm). Control wells will contain medium only.

**Assays of Fecal Porphyrins**

Feces will be collected from individual otters following the schedule of tissue sampling (Table 1).

*Oil Measurement in Feces*

A sample of 2.5 ml or g of feces will be placed into an extraction tube containing 4 mL isopropyl alcohol. The extraction tube will then be shaken for 1 minute to extract the PAH components. The extract will be filtered using a piston filter and then diluted 10-fold. This first dilution allows detection of 0.7 to 15 ppm PAH from the gauze saturated with isopropyl alcohol. If necessary a second dilution will be made to increase the detectable range to 140 ppm. The alkaline phosphatase hapten-enzyme conjuate will be added to the diluted sample and to a negative reference solution. The analyte detector used has a discrete sample reaction zone (sample zone) as well as a negative control reference reaction zone (reference zone), each of which contain latex particles that are coated with affinity-purified antibody. Five drops of prepared test sample will be added to the sample zone, and 5 drops of negative reference solution will be added to the reference zone of the detector. After 3 minutes, each solution will pass through the immobilized antibody and will be absorbed into the detector by capillary action. PAH in the sample will compete with the hapten-enzyme conjugate for sites on the immobilized antibodies. To remove any unbound hapten conjugate, 2 drops of rinse solution will be added to each reaction zone. To produce a color endpoint for the immunoassay, 2 drops of alkaline phosphatase color forming substrate will be added to each reaction zone which then reacted with the antibody bound hapten conjugate. As the concentration of PAH in the sample increases, the color endpoint decreases in intensity. A hand-held dual-beam reflectometer will be used to compare color intensity of the sample zone to the reference zone. The concentration of PAH in the isopropyl alcohol saturated gauze will be calculated from a preprogrammed standard curve and displayed by the reflectometer. The sensitivity, specificity, and predictive values of the test will be calculated by standard methods.

*Fecal Extraction*

The protocol used for extraction of fecal porphyrins is a modification of that developed by Lockwood et al. (1995). Five milliliters of 12N HCL will be added to approximately 1.0 g of dry (lyophilized) feces. This mixture will be vortexed, allowed to sit for 5 minutes, and vortexed again. Fifteen milliliters of both diethyl ether and distilled $H_2O$ will be added, and the mixture will be vortexed after each addition. To ensure that the porphyrins will be not denatured, the time elapsed between the addition of HC1 and $H_2O$ will not exceed 10 minutes. This mixture will be then centrifuged at 3,000 RPM for 10 minutes. The aqueous phase will be centrifuged again at 4,000 RPM for 5 minutes, and the supernatant refrigerated in the dark until time of analysis. The aqueous phase, which contains all porphyrins, will be approximately 20 ml, and exact volumes will be recorded.

*Diode-array Spectrophotometry*

One milliliter of each fecal extraction will be measured spectrophotometrically using Perkins-Elmer diode-array spectrophotometer. Porphyrins have a characteristic absorbency in the Soret banc, between 390-440 nm. The high noise created by the dark color of aqueous phases complicates the spectra so the second derivative spectra (350-450 nm) will be obtained for all samples and standards. The relative concentration of total porphyrins will be obtained by relating the trough depth (as measured from the baseline) of a standard porphyrin kit (Porphyrin Products, Logan, UT) to the trough depth of each sample. Porphyrin could be detected in every sample with 0.76 nmoles being the lowest level detected in the 201 samples analyzed. The concentration of total porphyrins in each sample will be calculated from the equation:
Total Porphyrins (nmole/g dry feces) = TD*(6/stdTD)*20ml/(DW*VU)
where: TD=trough depth of sample, measured from baselines; 6/std TD=trough depth of standard kit (6nmole); DW=dry weight of sample initially used for extraction; VU=volume of sample used for diode array analysis.

*HPLC Analysis*

Two milliliters of the initial aqueous phase will be concentrated to approximately 1 ml using a SpeedVac concentrator. One-hundred fifty micorliters (µl) of each sample, which will be selected arbitrarily from the 201 extracted samples, will be injected into a Waters HPLC system to determine porphyrin profiles. A Waters 441 UV detector with a 405 nm filter will be used for sample analysis. A silica-C1 column with 5 µm packing will be obtained from Phenomenex, Inc. (Torrance, CA). The gradient solvent system for the HPLC used will be a modification of the procedure outlined by Lim and Peters (1984). Solvents for gradient elution will be 10% (v/v) acetonitrile in 1 M ammonium acetate (Solvent A) and 10% (v/v) acetonitrile in methanol (Solvent B). All solvents will be HPLC grade (Fischer Scientific, Inc.). Porphyrins will be separated for 40 minutes with a linear gradient elution from 100% A to 100% B, followed by isocratic elution at 100% B for 20 minutes, then returning to 100% A over a 5 minute period. The flow rate will be 1 ml/minute at room temperature.

**Behavioral Observations**

Observations on foraging behavior and success will be conducted in two forms: 1. direct observations; 2. frame by frame analysis of video tapes recorded during the experimental sessions (Ben-David et al., 1991).

Otters will be individually marked with observable ear tags and will be allowed to forage alone for 90 minutes in each session. In each session river otters will be offered one type of the four possible prey in equal biomass:

1. Large schooling fish (Dolly varden; *Salvelinus malma*).
2. Large nonschooling fish (Cottidae).
3. Small schooling fish (herring; *Clupea pallasii*).
4. Small nonschooling fish (Cottidae).

These prey types represent the types of fish prey available to river otters in PWS.

Nonschooling fish are most commonly occur in the intertidal and subtidal sections of the coast. These prey are slow moving and are easy for river otters to catch (Kruuk, 1995). On the other hand, these fish may be difficult to locate and may require longer dive duration than schooling fish. Schooling fish represent more pelagic prey and may require high energy expenditure in chase (Kruuk, 1995). We chose 2 different sizes of fish to investigate the role of energy returns from prey on diving behavior of otters.

During each session the following data will be collected by direct observations:

1. Active time spent foraging
2. Number of dives
3. Duration of dives.
4. Number of capture attempts.
5. Number of capture successes.
6. Giving-up time.
7. Recovery time

Additional evaluation of foraging behavior will be conducted from video films recorded by 3 video cameras positioned in the enclosures. Data will be transcribed from films using Eshckol-Wachman Movement Notation (Ben-David et al., 1991). Eshckol-Wachman Movement Notation is a mathematical representation of animal movements that allows quantitative evaluation of behavior. This method is being used extensively in studies of predatory, play, and drug-induced behavior (Ben-David et al., 1991; Pellis, 1981; Pellis and Officer, 1987). Data collected from video films will include the following categories:

1. Propulsion mode (Fish, 1994).
2. Dive depth.
3. Duration of dive at each depth.
4. Attack behavior.
5. Prey responses to attack.

Observations will be conducted on single otters following the schedule described previously (Table 1), as well as on groups of 3 otters to assess the differences in foraging efficiency of individual otters compared with those of otters in groups under conditions of oil contamination.

**Statistical Analysis**

After examination of blood profiles and immunological assays of otters (by Dr. A. Rebar), animals will be classified to their appropriate clinical state (effected, uncertain, not effected). We will use a Chi-Square analysis for tests of homogeneity of proportions among groups (Guenther 1973). For bioindicators we will use a repeated measures MANOVA (Johnson and Wichern, 1992) with haptoglobin, IL-6, P450, and total fecal porphyrins as dependent variables and before exposure and after exposure ($n = 12$) oil treatments as main effects. We will examine chronic effects by extending the comparison of repeated measurements into a period of time demeaned necessary to detect chronic effects, examining a full model with dosage as an effect. In addition to statistical analyses we will follow the groups of 3 otters (Table 1) as a case-study for signs of clinical effects from oiling.

Behavior will be analyzed using observation bouts as the unit of sampling with repeated measures analysis, i.e., blocking by individual to control for lack of independence among bouts. Percentage of time spent in the different behaviors will be modeled as dependent variables with sampling period, dosage and group size as main effects.

**C. Cooperating Agencies, Contracts, and Other Agency Assistance**

This project is a collaborative research project of scientists from a variety of State (ADFG), university, and private research centers. University of Alaska Fairbanks will be responsible for the research work order, and contracts to Purdue University and Woods Hole Oceanographic Institute to assess health and oil exposure parameters.
Various transport aircraft and vessels will be chartered from the private sector. Local fishermen will be contracted to provide live prey.

Professional services contracts and Research Work Order mechanisms will be used to transfer funds from Trustee Agencies to university and private cooperators on this project. These will include contracts to Purdue University, Western Ecosystems Technology, Woods Hole Oceanographic Institute and others.

## SCHEDULE

### A. Measurable Tasks for FY98 and FY99

This project will begin in FY98 and will be completed in 1999.

| | |
|---|---|
| Nov 1997: | Development and refinement of study design and integration (Fairbanks, Alaska). |
| Jan 1998: | Attend Annual Restoration Workshop (Anchorage) |
| Feb - Mar 1998: | Arrange logistics (boats, equipment, Sealife Center enclosures) |
| Apr - May 1998: | Live - trapping of otters and transport to Sealife Center (PWS) |
| Jun - Dec 1998: | Conduct experiments at Sealife Center (Seward) |
| Jan 1999: | 1. Release animals to the wild<br>2. Attend Annual Restoration Workshop (Anchorage) |
| Jan - Sep 1999: | Data entry, analysis, and write up (Fairbanks and Seward) |

**B. Project milestones and endpoints.**

FY 98: Data collection
FY 99: Data collection and report submission

**C. Completion Date**

The work will be completed by Sept. 1999.

## PUBLICATIONS AND REPORTS

No publications are expected in FY 98. All reports will be published in FY 99. We have an excellent record of publishing results from our research.

## PROFESSIONAL CONFERENCES

The senior scientists on this project will likely present project results at various forums in 1999. However, other than the annual *EVOS* meeting in January in Anchorage, presentations at professional conferences have not been identified or scheduled at this point. We propose to notify the Trustees of presentations and forums as they are scheduled.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The project is closely linked with the river otter section of the NVP project and with the Sealife Center in Seward. We have discussed the project with Dr. Leslie Holland Barttles, Chief Scientist for NVP.

## PRINCIPAL INVESTIGATORS

**Dr. Merav Ben-David**
Institute of Arctic Biology
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Merav Ben-David, Ph.D. is a research associate with the institute of Arctic Biology University of Alaska Fairbanks. She has extensive experience in studying behavior of mammals and birds under captive conditions. Her research concentrates on mustelids and predatory behavior. She is currently funded for three projects one of which involves developing new DNA techniques to estimate population levels of river otters (ASTF). She is an active member of the IUCN/SSC otter specialist group. Her responsibilities in this project include the foraging behavior and project coordination.

**Dr. R. Terry Bowyer**
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Dr. R. Terry Bowyer, Professor of Wildlife Ecology, University of Alaska Fairbanks. Dr. Bowyer has an extensive publication record (70). He has conducted extensive research on river otters and impacts of *EVOS* on this species (10 publications), and has experience conducting behavioral research.

**Dr. Lawrence K. Duffy**
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Dr. Lawrence Duffy, Professor of Chemistry and Biochemistry at the University of Alaska Fairbanks has been working in the area of toxicology for 15 years and is a member of the International Society of Toxicology. He has studied various bacterial and mammalian toxins. Since the *Exxon Valdez* oil spill, he has published six papers related to developing biomonitors. He is currently funded for two major environmental studies in Alaska. At the University, he teaches "Environmental Biochemistry and Biotechnology" and is a member of the Environmental Chemistry Program and Mammal Group. His responsibilities in this project will be to conduct the biomarkers analysis.

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**

October 1, 1997 - September 30, 1998

Approved TC 8-6-97

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | | $0.0 | | | | | | |
| Travel | | $0.0 | | | | | | |
| Contractual | | $188.1 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | $0.0 | $188.1 | | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| General Administration | | $13.2 | | | | | | |
| Project Total | $0.0 | $201.3 | | | | | | |
| Full-time Equivalents (FTE) | | 0.0 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

TOTAL PROJECT COST:

$201.3
+ 44.1 bench fees
$ 245.4

**1998**

Prepared: 1 of 1

Project Number: 98348
Project Title: Responses of River Otters to Oil Contamination
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

9/9/97

Revised 4-97
Approved TC 8-6-97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $63.9 |
| Travel | | $15.1 |
| Contractual | | $62.8 |
| Commodities | | $8.7 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $150.5 |
| Indirect | | $37.6 |
| Project Total | $0.0 | $188.1 |
| Full-time Equivalents (FTE) | | 16.5 |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 |
|---|---|---|---|
| $165.0 | $0.0 | $0.0 | $0.0 |

Dollar amounts are shown in thousands of dollars.

Comments:
1. Indirect at 25% of direct costs as agreed with the University of Alaska Fairbanks.
2. 30% of direct costs will be spent on community involvement.
3. 4% of direct costs will be spent on attending workshops.
4. Bench fees for housing otters in the Sealife Center will be negotiated directly between Trustees council and Sealife cooredinator at a later date.
5. Travel from lower 48 for Dr. Lyman McDonald to attend Restoration meeting and discuss study design. Travel from Europe for Dr. Hans Kruuk for visit of the Seward facility and consulattion on acclimation of animals.

**1998**

Project Number: 98348
Project Title: Responses of river otters to oil contamination: a controlled study of biological stress markers
Name: Institute of Arctic Biology - UAF

FORM 4A
Non-Trustee
SUMMARY

Prepared: April 8 1997



6/17/97

## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 1998 |
| M. Ben-David | Principle investigator - coordinator | | 9.0 | 4.5 | | 40.5 |
| R. T. Bowyer | Principle investigator-analysis and rep | | 1.0 | 9.7 | | 9.7 |
| L. K. Duffy | Principle investigator - lab analyses | | 0.0 | 10.2 | | 0.0 |
| Vacant | Technician - assist in data collection | | 6.5 | 2.1 | | 13.7 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 16.5 | 26.5 | 0.0 | |
| | | | | | **Personnel Total** | $63.9 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 1998 |
| Travel to Fairbanks from lower 48 | 0.7 | 1 | 5 | 0.1 | 1.2 |
| Travel to Fairbanks from Europe | 2.5 | 1 | 5 | 0.1 | 3.0 |
| Travel to Seward | 0.3 | 8 | 44 | 0.1 | 6.8 |
| Travel to Anchorage | 0.3 | 2 | 10 | 0.2 | 2.6 |
| Travel to PWS | 0.3 | 5 | 150 | 0.0 | 1.5 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $15.1 |

**1998**

Project Number:
Project Title: Responses of river otters to oil contamination: a controlled study of biological stress markers
Name: Institute of Arctic Biology - UAF

FORM 4B
Personnel
& Travel
DETAIL

Prepared: April 8 1997



6/17/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Charter plane for otter transport @ $800 x8 | 6.40 |
| Charter a boat for trapping @ $950 x30 | 28.50 |
| Contract fishermen to obtain live prey | 20.00 |
| Statistical consultation | 4.80 |
| Duplication and computer fees | 2.50 |
| Telephone | 0.60 |
| **Contractual Total** | $62.8 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Food - mink chow | 5.0 |
| Blood collection/ storage supplies | 3.5 |
| Diskettes and misc. | 0.2 |
| **Commodities Total** | $8.7 |

**1998_**

Prepared: April 8 1997
3 of 4

Project Number:
Project Title: Responses of river otters to oil contamination: a controlled study of biological stress markers
Name: Institute of Arctic Biology - UAF

FORM 4B
Contractual & Commodities

4/17/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| New Equipment Purchases: Description | Number of Units | Unit Price | Proposed FY 1998 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of a | | **New Equipment Total** | $0.0 |

| Existing Equipment Usage: Description | Number of Units |
|---|---|
| No 11 Sleepy Creek leghold traps | 50 |
| Telonics trap monitoring transmitters | 30 |

**1998**

Prepared: April 8 1997

Project Number:
Project Title: Responses of river otters to oil contamination: a controlled study of biological stress markers
Name: Institute of Arctic Biology - UAF

FORM 4B
Equipment
DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $41.2 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $41.2 |
| General Administration | | $2.9 |
| Project Total | $0.0 | $44.1 |
| Full-time Equivalents (FTE) | | 0.0 |
| Other Resources | | |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 | |
| | | | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

Contractual funds are for bench fees at the Alaska SeaLife Center.

**1998**

Prepared: 1 of 1

Project Number: 98348
Project Title: Bench Fees: Responses of River Otters to Oil Contamination
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

9/9/97

Approved TC 8-6-97

# *Exxon Valdez* Restoration Reserve Fund

| | |
|---|---|
| **Project Number:** | 98424 |
| **Restoration Category:** | Restoration Reserve |
| **Lead Trustee Agency:** | All Trustee agencies |
| **Duration:** | Ongoing |
| **Cost FY 98:** | $12,000,000 |
| **Cost FY 99:** | $12,000,000 |
| **Cost FY 00:** | $12,000,000 |
| **Cost FY 01:** | $12,000,000 |
| **Cost FY 02:** | $12,000,000 |
| **Geographic Area:** | Oil spill area |
| **Injured Resource/Service:** | Multiple resources and services |


## ABSTRACT

In recognition of the fact that complete recovery from the oil spill may not occur for decades, the Trustee Council established the Restoration Reserve to hold funds to be used for restoration after the last annual payment is received from the Exxon Corporation in September 2001. The $12 million recommended for deposit in FY 98 would be the fifth deposit into the reserve account, and would bring the total in the account to $60 million. Annual deposits of $12 million in each of the next four years would provide a reserve of $108 million plus interest.

## INTRODUCTION

Complete recovery from the *Exxon Valdez* oil spill may not occur for decades. In many cases, substantial research must precede effective restoration or improved management actions that will protect a resource or service, and long-term monitoring can be necessary to understand the effectiveness of specific restoration actions. The *Exxon Valdez* Restoration Reserve Fund could potentially benefit any resource or service injured by the oil spill. No allocation of Restoration Reserve funds to specific activities has yet been made.

## NEED FOR THE PROJECT

The Chief Scientist and other investigators working on the restoration program have identified a clear need to maintain restoration activities in the years following Exxon's last scheduled payment in 2001. The collection of long-term data sets is increasingly recognized as essential to understanding the results from any one year's work. For example, some salmon return in cycles of four to six years, and other resources have lives that are much longer. To be effective, restoration activities may have to span more than one generation. Oceanographic influences on the health and survival of numerous injured species under investigation are only just beginning to be understood. Work under the major ecosystem studies, while providing significant new insight into the status of recovery and health in the spill area, is also bringing attention to new questions that may require continuing efforts long into the future. In addition, there continues to be interest in the Trustee Council's large and small parcel habitat protection program efforts. Funds in the Restoration Reserve may be used for any purpose consistent with the civil settlement.

## PROJECT DESIGN

This proposed $12 million would be the fifth payment to the *Exxon Valdez* Restoration Reserve Fund. Based on previous action of the Trustee Council, the total principal after this deposit would be $60 million. Additional annual deposits of $12 million in each of the remaining five years would provide a reserve of $108 million plus interest from investment of these funds. This amount is expected to be appropriate to carry out long-term restoration activities after the last Exxon payment.

### A. Objectives

The essential objective for the Restoration Reserve Fund is to ensure that funds are available as necessary for the Trustee Council to continue restoration activities beyond the end of the settlement payment period.

## B. Methods

The Restoration Reserve funds are currently invested in laddered securities within the Court Registry Investment System; accrued earnings remain with the Restoration Reserve. Other options for investment are currently being researched. The Restoration Office will conduct public meetings during FY 98 to obtain public comment on future use of the Restoration Reserve. The planning process will include workshops in communities in the spill area as well as Juneau, Anchorage and Fairbanks. Any spending from the Restoration Reserve must be consistent with the Consent Decree and with the Memorandum of Understanding between the state and federal governments. The $12 million proposed for FY 98 will be transferred from the Court Registry Investment System Liquidity Fund to the Restoration Reserve Fund by Court order when such amount is available once pending restoration needs are funded.

## C. Schedule

It is anticipated that by fall 1998, the Trustee Council will make a decision about the future use and management of the Restoration Reserve.

## D. Technical Support

Not applicable.

## E. Location

Oil spill area.

Approved TC 8-6-97

# Harlequin Duck Recovery Monitoring

| | |
|---|---|
| Project Number: | 98427-CLO |
| Restoration Category: | Monitoring |
| Proposer: | D. Rosenberg/ADFG |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | No |
| New or Continued: | Cont'd |
| Duration: | 5th yr.<br>5 yr. project |
| Cost FY 98: | $78.3 |
| Cost FY 99: | $0.0 |
| Cost FY 2000: | $0.0 |
| Cost FY 01: | $0.0 |
| Cost FY 02: | $0.0 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | Harlequin duck |

**ABSTRACT**

This project will complete the harlequin duck recovery monitoring project (/427). A final report and manuscripts will be prepared, reporting on the findings of this multi-year project.

## INTRODUCTION

Harlequin ducks (*Histrionicus histrionicus*) occur year-round in intertidal zones of PWS (Isleib and Kessel 1973). Approximately 1,000 harlequin ducks died as a direct result of oil exposure following the Exxon Valdez oil spill (ECI 1991). Oil spill studies of harlequin ducks in western Prince William Sound (PWS) from 1990-93 found consistently low numbers of birds during the breeding season, a lack of breeding activity on suitable streams in 1991 and 1992, negligible production of broods through 1993, and an apparent decline in post-breeding molting birds (Patten 1995, Patten et al. 1995). Nearly five years after the Exxon Valdez oil spill there was no sign of recovery (Exxon Valdez Oil Spill Trustee Council 1993).

Two main hypotheses were presented to explain lack of reproduction and population declines: (1) ingested oil is continuing to cause either mortality and/or sublethal impairment of reproduction; and/or (2) initial mortality caused significant losses to the local western PWS breeding component and subsequent low production. Postspill studies indicated an initial decline in molting birds, a lack of productivity, and fewer breeding pairs present in spring in oiled areas, although no conclusive evidence has been found of histological or physiological effects from oil.

In response to this lack of recovery, project /427, Harlequin Duck Recovery Monitoring was begun in 1994 with a pilot project to develop age criteria and survey methods to compare the population structure, numbers, and distribution during spring in oiled and unoiled areas of PWS. Studies were expanded in late-spring 1994 to compare molting populations and measure production (brood surveys). Age and sex criteria and a survey design were developed and complete spring and fall surveys were conducted in 1995, 1996, and 1997. A winter survey was added in 1997. Annual Reports were prepared for each years survey results (Rosenberg 1995, Rosenberg et al. 1996, Rosenberg and Petrula 1997).

This project will prepare a final report and manuscripts for publication in peer reviewed journals. Because the FY97 field season ends close to the end of the fiscal year, money is also allocated for equipment maintenance and storage.

## NEED FOR THE PROJECT

### A. Statement of Problem

Prior to 1994, EVOS projects gathered abundance and distribution data mostly on total harlequin ducks, with little information on sex and age composition, or proportions of paired birds. The focus of these projects was extensive survey coverage and oil exposure studies. Sea duck populations, in general, are composed of long-lived birds that have delayed sexual maturity, low annual production rates, and "boom and bust" years. Consequently, sea duck population dynamics are quite sensitive to adult female survival rates, size of the breeding component, and variable breeding propensity (% of adults breeding annually). Data on sex and age composition are very useful in examining these aspects of a population.

The consistently low numbers of birds during the breeding season, a lack of breeding activity on suitable streams in 1991 and 1992, negligible production of broods through 1993, and an apparent decline in post-breeding molting birds all led to concern for harlequin duck populations and the need to monitor the population structure and productivity of this species and assess its recovery.

### B. Rationale/Link to Restoration

These surveys assessed recovery of harlequin duck populations and sought to identify factors inhibiting or contributing to recovery and restoration. Monitoring provided information on population structure and growth. Focus on these population parameters is necessary to determine the status and recovery potential of harlequin ducks; determine if recovery objectives are being met; and suggest factors limiting recovery. The monitoring effort also allowed us to modify recovery objectives as new information became available. This provided a more reliable basis for restoration planning and was consistent with an adaptive management approach that allowed more efficient allocation of efforts and enrichment of knowledge over time.

This report will consider a variety of population parameters and assess whether the lack of production in western Prince William Sound; lower breeding propensity; higher female mortality; and the suspected high degree of site fidelity to nesting and molting areas has interfered with population recovery in oiled areas. A continued decline in harlequin duck populations in western Prince William Sound may lead to a significant reduction or loss of this resource from the area and beyond. It is important to know if populations are continuing to decline, and if so, understand the factors responsible for limiting recovery. Populations may continue to decline due to a lack of recruitment, greater mortality, oil toxicity, or a combination of factors.

### C. Location

This report will include survey results from oiled portions of western PWS and unoiled portions of eastern PWS (Rosenberg 1995, Rosenberg et al. 1996, Rosenberg and Petrula 1997). No new field work will be conducted.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

This report will include information gathered on Traditional Ecological Knowledge of harlequin ducks in PWS. Project personnel will adhere to the EVOS Restoration Office protocols for including indigenous knowledge in the restoration process. The project will inform and coordinate our community involvement activities, including the collection of indigenous knowledge with Dr. Henry Huntington, TEK specialist EVOS Restoration Office; Martha Vlasoff, community coordinator; and the Subsistence Division of the Alaska Department of Fish and Game.

No funding has been requested for travel to local communities to present information on TEK of the findings of this study.

## PROJECT DESIGN

### A. Objectives

FY 98:

1) Analyze data from FY97 field season;

2) Incorporate data in current Geographical Information System developed for these studies;

3) Prepare final report including all information gathered from 1994-1997.

4) Prepare 2-3 manuscripts for publication in peer reviewed journals.

### B. Methods

Statistical analysis will follow methods in previous annual reports (Rosenberg 1995, Rosenberg et al. 1996, Rosenberg and Petrula 1997).

### C. Cooperating Agencies, Contracts, and Other Agency Assistance

Unpublished data will be shared with USGS-BRD, project \025 Nearshore Vertebrate Predator project. No contracts will be solicited for this report.

## SCHEDULE

### A. Measurable Project Tasks for FY 98

| | |
|---|---|
| October-December: | Maintain and store field equipment.<br>Data entry and analysis.<br>GIS and map preparation.<br>Begin final report and manuscript preparation. |
| January-March: | Attend EVOS Restoration Workshop.<br>Continue data analysis and report preparation. |
| April 15: | Submit final report and manuscripts. |

### B. Project Milestones and Endpoints

FY99

| | |
|---|---|
| October-March: | Publish manuscripts. |

C. Completion Date

All project objectives will be met following FY99.

## PUBLICATIONS AND REPORTS

A final report of FY94-FY97 activities will be submitted to the Restoration Office before April 15, 1998. Manuscripts for peer reviewed journals will be submitted for publication prior to November 1, 1998.

## PROFESSIONAL CONFERENCES

A paper will be presented to the Harlequin Duck Working Group biennial meeting to be held in March 1998. Location to be announced.

## 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

Results will be compared and integrated with other EVOS Trustee sponsored research, including projects /025 Nearshore Vertebrate Predator Project, /161 Harlequin duck genetics, /159 Prince William Sound Marine Bird Surveys, and /052B Traditional Ecological Knowledge. Information from this project will support proposed project 98426 Harlequin Duck Population Dynamics-Patterns and Processes. Results from Crowley (1966) , EVOS Restoration project R71, will be incorporated into manuscripts.

## PROPOSED PRINCIPAL INVESTIGATORS

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Revision (5-9-1
Approved TC 6-6-97

# 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Budget Category: | Authorized FY 1997 | Proposed FY 1998 |
|---|---|---|
| Personnel | $165.1 | $60.2 |
| Travel | $9.4 | $1.6 |
| Contractual | $33.5 | $5.3 |
| Commodities | $16.5 | $1.8 |
| Equipment | $0.9 | $0.0 |
| Subtotal | $225.4 | $68.9 |
| General Administration | $27.1 | $9.4 |
| Project Total | $252.5 | $78.3 |
| Full-time Equivalents (FTE) | 2.8 | 1.0 |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 1999 | Estimated FY 2000 | Estimated FY 2001 | Estimated FY 2002 |
|---|---|---|---|
| $1.0 | $0.0 | $0.0 | $0.0 |

Dollar amounts are shown in thousands of dollars.

Other Resources

Comments: Close Out for Project 98427 Harlequin Duck Recovery Monitoring. No field work is proposed for this project in FY98. No money is allocated for NEPA compliance. Only salary money is allocated for attendance at Anchorage workshops. Page costs for publication in peer reviewed journals is not included because manuscripts may not appear in print in FY98. Page costs for publication are included in FY99. Project includes costs to repair, maintain, and store boats and field gear following the FY97 field season which ends in mid-September, 1997.

**1998**

Prepared: April 97

Project Number: 98427 CLO
Project Title: Harlequin Duck Recovery Monitoring
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY



6/25/97

## 1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1997 - September 30, 1998

| Personnel Costs: | | GS/Range/ Step | Months Budgeted | Monthly Costs | Overtime | Proposed FY 1998 |
|---|---|---|---|---|---|---|
| Name | Position Description | | | | | |
| D. Rosenberg | WBIII, Principle Investigator | 18F | 4.0 | 6.2 | | 24.8 |
| Mike Petrula | WBI, Data analysis, report prep., graphics | 14C | 4.0 | 4.1 | | 16.4 |
| Dave Crowley | WBI, Manuscript preparation | 14D | 1.0 | 4.3 | | 4.3 |
| E. Becker | Biometrician II | 19L | 1.0 | 6.9 | | 6.9 |
| C. Barnhill | Cartographer II | 16L | 1.5 | 5.2 | | 7.8 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 11.5 | 26.7 | 0.0 | |
| | | | | | **Personnel Total** | $60.2 |

| Travel Costs: | Ticket Price | Round Trips | Total Days | Daily Per Diem | Proposed FY 1998 |
|---|---|---|---|---|---|
| Description | | | | | |
| Harlequin Duck Working Group Meet. Loc.and date TBA 1/ | 8.0 | 1 | 6 | 0.1 | 1.2 |
| Rental Car-Harlequin Duck Working Group | | | 6 | | 0.3 |
| Airport parking, taxi fare, EVOS Workshop parking. | | | | | 0.1 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $1.6 |

1/ The Harlequin Duck Working Group Meeting is an international Workshop that meets every other year. The 1998 meeting is expected to be held in Vancouver, BC or in the State of Maine.

**1998**

Project Number: 98427 CLO
Project Title: Harlequin Duck Recovery Monitoring
Agency: ADFG

FORM 3B
Personnel
& Travel
DETAIL

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Warehouse for equipment storage and maintenance - 5 months @ $775/mo | 4.0 |
| Boat and outboard motor repair and maintenance | 1.0 |
| Photo processing, Workshop presentation productions | 0.3 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $5.3 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 1998 |
| Computer software for analysis, graphing, mapping | 1.0 |
| Equipment Maintenance | 0.8 |
| **Commodities Total** | $1.8 |

**1998**

Prepared:April 97

Project Number: 98427 CLO
Project Title: Harlequin Duck Recovery Monitoring
Agency: ADFG

FORM 3B
Contractual & Commodities DETAIL



6/25/97

**1998 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 1997 - September 30, 1998

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 1998 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

| **Existing Equipment Usage:** Description | Number of Units | Inventory Agency |
|---|---|---|
| | | |

**1998**

Prepared: April 97
4 of 4

Project Number: 98427 CLO
Project Title: Harlequin Duck Recovery Monitoring
Agency: ADFG

FORM 3B
Equipment
DETAIL

6/25/97