Sound Ecosystem Assessment (SEA): Observational Oceanography in Prince William Sound and the Gulf of Alaska.

Project Number:	99320-M
Restoration Category:	Research
Proposer:	Prince William Sound Science Center
Sponsoring Agency:	
Duration:	One year
Cost FY 99:	$ 72.8 K
Cost FY 00:	$0 K
Cost FY 01:	$0 K
Cost FY 02:	$0 K
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink salmon and Pacific Herring

ABSTRACT

The model validation portion of the FY97 SEA Observational Oceanography project (320-M) has not been completed. Model validation is required before the model can be used for hypothesis testing by any of the SEA projects. Fund were remaining in the 320-M FY97 budget at the end of the year. This proposal is for funding, in the amount remaining in FY97,
to cover salaries of personnel responsible for circulation model validation and zooplankton seeding/flushing hypothesis testing.

INTRODUCTION

Three main goals of SEA are to (1) understand the interactions between physical and biological processes that influence pink salmon and Pacific herring production, (2) develop coupled physical/biological numerical models to describe those interactions, along with a cost effective monitoring strategy to provide model input data, and (3) create a comprehensive data base linking and providing access to all SEA data. Understanding and monitoring key processes, along with numerical model predictions of fish distribution and abundance, will benefit long term management stratagies.

Informed management decisions will enhance the restoration of pink salmon and Pacific herring, as well as other marine resources.

The SEA Observational Oceanography project has responsibilities in 3 main areas:

1. Large scale (Sound wide) physical and biological descriptive oceanography, relating phytoplankton and zooplankton distributions to physical processes.
2. Nearshore physical and biological descriptive oceanography, relating juvenile herring distributions to physical processes.
3. Numerical circulation model validation and testing.

The first 2 items in the SEA FY97 DPD (page 129)) under 'Physical field measurements', continuing ADCP velocity measurements at Hinchinbrook Entrance and Montague Strait and calculating transports, and continuing large scale hydrographic and velocity measurements, have been completed. The 1997 May cruise data have been processed, and we retrieved the ADCP mooring from Hinchinbrook Entrance and processed the data. We also completed a Sound-wide survey of zooplankton distributions using the OPC (item 5). The last 2 items, about critical regions and times, and designing a cost-effective monitoring scheme, are addressed in a recent FY99 DPD submitted to EVOS.

The third and fourth items in FY97 DPD, about assimilating data into the model, and identifying 'river' and 'lake' conditions, are only partially completed. The version of the model that is running now has freshwater input distributed uniformly over the surface. The model temperature profiles agree with the observations, but the modeled and observed salinities are not in agreement, especially in September (highest freshwater runoff).

The version of the model being constructed now (under SEA 320-J) will have freshwater input distributed around the periphery of the Sound, which is much more realistic. This version will also have more realistic inflow/outflow at Hinchinbrook Entrance, provided by the ADCP mooring time series. The current model version has inflow at all levels. After this newer model version is validated, it will be used to test hypothesis about zooplankton seeding and flushing in PWS.

The newer version of the model was scheduled for completion in January 1998. Because of personnel changes (in 320-J), this work is only now nearing completion. It is the validation of this newer model version, and finalizing our 'river/lake' analysis that remains to be done. This proposal is for funds to cover salaries of personnel responsible for completing these tasks.

NEED FOR THE PROJECT

A. Statement of the Problem

Pink salmon and Pacific herring resources continue to be listed as injured and non-recovering. SEA is an interdisciplinary ecosystem approach to understand which biological and physical factors in the environment might be constraining the recovery of these species. Predicting the impact of physical

processes on the biological components requires the coupling of a numerical ocean circulation model with a biological model. Other projects in SEA are working toward developing such a coupled model for PWS, but these models need observations for validation. This project will contribute the oceanographic data and analytic techniques for validation and refinement of the numerical circulation model, and for hypothesis testing.

B. Rationale/Link to Restoration

Without understanding how environmental and ecological factors might be influencing the recovery of injured species, there is no clear means for interpreting the past and present production status of pink salmon and herring in Prince William Sound. Further, restoration activities undertaken in the absence of knowledge about ecosystem function could conceivably cause more damage than they are intended to remedy. In the short term, development of improved stock assessment techniques and their application to building and evaluating numerical models of the herring and pink salmon ecosystem will improve the tools available for harvest management. Over the long term, as the SEA program obtains a better understanding of ecosystem form and function in Prince William Sound, the risks associated with proactive restoration activities will become much less uncertain. The numerical models developed by SEA will allow a variety of "what if" restoration options to be evaluated prior to their implementation as a measure for protecting all resources in the region.

Physical processes (tides, storms, inflow from the GOA, etc.) determine the water mass properties (temperature and salinity) and the circulation of PWS. Water mass properties and circulation influence the abundance and distribution of phytoplankton and zooplankton. Since zooplankton are the major food source for juvenile fish, their availability directly impacts the abundance and distribution of pink salmon and herring in PWS. Describing the character and evolution of the water mass properties and circulation in PWS, and identifying which physical processes are primarily responsible for changes in the water mass properties and circulation, will ultimately lead to correlations between those physical processes and fish abundance.

C. Location

This project has been designed for Prince William Sound. All communities that utilized the marine resources of Prince William Sound will benefit from this research.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

This project has contributed to the EVOS Youth Area Watch by designing a low cost program for high school students to monitor coastal oceanographic and meteorological variables at several locations in PWS. EVOS students participated in an oceanographic research cruise in 1996. This collaboration is expected to continue. Local fishing vessels and ships were chartered for oceanographic cruises in FY94 through FY97. Coast Guard and SERVs vessels have also been used for oceanographic surveys. This project has contributed information to local news letters, newspaper articles, seminars, and the Sound Waves radio program, and will continue to do so. Scientific results have been posted on the SEA web page, and are accessible to the public.

PROJECT DESIGN

A. Objectives

The main objective of this proposal is to complete tasks scheduled for FY97 so that the SEA project will close-out on schedule. These task are:

1. Validate the newest version of the numerical circulation model.

2. Use the model and the observations to test hypothesis about zooplankton seeding and flushing rates ('river/lake' hypothesis) in PWS.

B. Methods

1. Model generated horizontal fields of temperature, salinity, and current velocity at several standard depths (surface, 20m, 50m, 100m, etc.) for the months where cruise data exist will be compared to the observations. Vertical sections of modeled temperature, salinity, and current velocity will be compared sections created from the data. Success of the model simulations will be judged by the level of agreement between predicted and actual magnitudes of the variables, horizontal and vertical distributions of the variables, the seasonal variability (stratification formation, warming, and freshening), and the ability of the model to simulate large scale, robust features of the circulation and hydrographic structure of PWS (e.g. basin scale cyclonic circulation in September).

2. A passive tracer concentration, simulating zooplankton, will be placed at some location and depth in the model, for example mid-depth at Hinchinbrook Entrance, or deep in the 'black hole'. The model will be allowed to run, forced by seasonal meteorological fields, predicting the evolution (both horizontally and vertically) of the tracer field. The wind forcing, the inflow at Hinchinbrook Entrance, and the amount of freshwater input, for example, may be varied in the model runs to examine the effects of each. The spreading and evolution of the tracer field will be used to infer zooplankton distribution under different conditions. The model predictions will be compared to the observations.

C. Cooperating Agencies, Contracts and Other Agency Assistance

In previous years, vessel charters have been contracted to the private sector through competitive bid.

SCHEDULE

A. Measurable Project Tasks for FY 99

March 1999: EVOS Workshop - 10th Anniversary, and SEA Review
April 15, 1999: Submit SEA FY98 Draft Annual Report

April 15, 2000: Submit SEA FY99 Draft Final Report

B. Project Milestones and Endpoints

FY99: Submission of publication to peer reviewed journal.

D. Completion Date

The completion date will be September 30, 1999.

PUBLICATONS AND REPORTS

One manuscript will be submitted on comparisons between model simulations and observations in PWS.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Efforts in Observational Physical Oceanography are coordinated with all components of the SEA program. Research cruises and much of the data collected are shared with other SEA investigators. SEA will also cooperate with APEX and other EVOS-sponsored programs to provide the most efficient means for investigating biological and environmental factors common to all projects.

PROPOSED PRINCIPAL INVESTIGATOR

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PRINCIPAL INVESTIGATOR

Shari L. Vaughan, Ph.D.
Physical Oceanographer, Prince William Sound Science Center

Education:

B.S., University of Miami, May 1981, Physics (major)/Mathmatics (minor)
M.S., University of Miami, May 1986, Physics
Ph.D., University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS), May 1993, Meteorology and Physical Oceanography (MPO), Kevin D. Leaman, advisor

Professional Experience (since 1986):

1986 - 1993: Research Assistant, University of Miami, RSMAS, MPO, Miami, Florida
1993 - 1995: Postdoctoral Associate, University of Miami, Cooperative Institute for Marine and Atmospheric Studies, a cooperative institute between RSMAS and NOAA's Atlantic Oceanographic and Meteorologica Laboratory (AOML), Miami, Florida, Robert L. Molinari, supervisor
Sept. 1995 - present: Physical Oceanographer, Prince William Sound Science Center, Cordova, Alaska

Recent Refereed Journals:

Vaughan, S. L. and K. D. Leaman, 1995: The Role of Small-Scale Cells in the Mediterranean Convection Process. *J. Phys. Oceanogr.,* **25** (10), 2423-2436.

Vaughan, S. L. and R. L. Molinari, 1997: Temperature and Salinity Variability in the Deep Western Boundary Current. *J. Phys. Oceanogr.,* (accepted, May issue).

OTHER KEY PERSONNEL

Funding is also requested for personnel Shelton M. Gay, Loren Tuttle, and Kenric Osgood. Vaughan, Gay, and Osgood will be primarily responsible for the physical comparisons. Tuttle and Osgood will be primarily responsible for the zooplankton comparisons.

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel		$0.0
Travel		$0.0
Contractual		$71,370.0
Commodities		$0.0
Equipment		$0.0
Subtotal	$0.0	$71,370.0
General Administration		$1,439.9
Project Total	$0.0	$72,809.9
Full-time Equivalents (FTE)		10.5

LONG RANGE FUNDING REQUIREMENTS					
	Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		
	$0.0	$0.0	$0.0		

Dollar amounts are shown in thousands of dollars.

Other Resources								

Comments:

FY 99

Prepared:

Project Number: 99-320M
Project Title: SEA: Observational Oceangraphy in PWS and GOA
Agency:

FORM 3A
TRUSTEE
AGENCY
SUMMARY

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel		$59,475.0
Travel		$0.0
Contractual		$0.0
Commodities		$0.0
Equipment		$0.0
Subtotal	$0.0	$59,475.0
Indirect (20.0%)		$11,895.0
Project Total	$0.0	$71,370.0
Full-time Equivalents (FTE)		10.5
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

	Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		

Dollar amounts are shown in thousands of dollars.

Comments:

FY 99

Prepared:

Project Number: 99-320M
Project Title: SEA: Observational Oceangraphy in PWS and GOA
Agency:

FORM 4A
Non-Trustee
SUMMARY

FY 99 EXXON VALDEZ TRU[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Personnel Costs:			Months	Monthly		Proposed
	Name	Position Description	Budgeted	Costs	Overtime	FY 1999
	Shari Vaughan	Physical Oceanographer (PI)	3.0	7100.0		21,300.0
	Shelton Gay	Physical Oceanographer	2.5	5300.0		13,250.0
	Loren Tuttle	Biological Oceanographer	2.5	4800.0		12,000.0
	Kenric Osgood	Biological Oceanographer	2.5	5170.0		12,925.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	10.5	22370.0	0.0	
					Personnel Total	$59,475.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 1999
						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

FY 99

Prepared:

Project Number: 99-320M
Project Title: SEA: Observational Oceangraphy in PWS and GOA
Agency:

FORM 4B
Personnel
& Travel
DETAIL

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
Contractual Total	$0.0

Commodities Costs:	Proposed FY 1999
Description	
Commodities Total	$0.0

FY 99

Prepared:

Project Number: 99-320M
Project Title: SEA: Observational Oceangraphy in PWS and GOA
Agency:

FORM 4B
Contractual & Commodities DETAIL

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
			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	

FY 99

Project Number: 99-320M
Project Title: SEA: Observational Oceangraphy in PWS and GOA
Agency:

FORM 4B
Equipment
DETAIL

Prepared:

Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the *Exxon Valdez* Oil Spill: Preparation of Manuscripts for Publication - Submitted Under BAA

Project Number:	98325
Restoration Category:	Research
Proposer:	Coastal Resources Associates, Inc.
Lead Trustee Agency:	NOAA (Submitted Under BAA)
Cooperating Agencies:	ADF&G
Alaska SeaLife Center:	No
Duration:	2nd year, 3-year project
Cost FY 98:	$104,096
Cost FY 99:	$ 41,192
Cost FY 00:	$ 800
Cost FY 01:	None
Cost FY 02:	None
Geographic Area:	No Field Work Proposed, Past Work in Prince William Sound, Kenai/Cook Inlet, and Kodiak/Alaska Peninsula
Injured Resource/Service:	Intertidal and Subtidal Communities

ABSTRACT

This project will prepare manuscripts for publication in scientific journals based on previous Trustee funded evaluations of injury to, and restoration of, coastal habitats (intertidal and subtidal communities).

INTRODUCTION

The *Exxon Valdez* Oil Spill Trustee Council (hereafter referred to as the EVOS Trustees) has funded a number of projects that examined the injury to, and recovery of intertidal and nearshore subtidal systems. These include Coastal Habitat Study 1A: Comprehensive Assessment of Coastal Habitat; Restoration Project 94086: Herring Bay experimental monitoring studies; and several projects dealing with nearshore subtidal communities (Air/Water Project ST2A, and Restoration Projects 93047 and 95106). The final reports for these projects have been submitted to the Trustees (Highsmith *et al.* 1994, 1995; Jewett *et al.* 1995; and Jewett and Dean 1996) and several aspects of this work have either been published or are submitted for publication in the peer reviewed scientific literature (see Literature Cited). However, there are still several important scientific aspects of this work that have not been published.

In April 1997, a proposal was submitted to the EVOS Trustees to prepare manuscripts based on past EVOS work. The project (98325) was funded, with separate contracts awarded to Coastal Resources Associates, Inc. and WEST, Inc. (through NOAA under BAA) and to the University of Alaska (through ADF&G). Unfortunately, funding for the project was delayed and did not become available until February, 1998. As a result, there has been slower progress toward manuscript submittal than originally proposed. However, substantial progress has been made. One manuscript proposed for submission in FY 1998 was submitted in February 1998 and is in review. A draft of another has been completed and is under internal review, and for three others, manuscripts have been outlined and progress made toward gathering and analyzing data. This proposal seeks additional funding for FY 1999 to complete additional manuscripts as proposed in April of 1997. We anticipate that funding will of course be contingent upon submittal of manuscripts for which funds have already been received.

NEED FOR THE PROJECT

A. Statement of Problem

Publication of past Trustee sponsored studies of coastal habitats is important because these studies serve as a critical foundation for future injury assessment and restoration efforts. These studies are the most thorough and comprehensive investigations of a major oil spill that have been conducted to date, and should serve as cornerstone for future oil spill studies. Some of the Trustee sponsored work has recently been criticized (e.g. Paine *et al.* 1996) and a timely publication of coastal habitat studies is needed in order to correct some current misconceptions.

B. Rationale/Link to Restoration

The lessons learned from studies of coastal habitats following the *Exxon Valdez* oil spill, both about the ecology of the nearshore environment and about the process of assessing impacts from a major oil spill, are valuable ones that need to be applied to future restoration efforts.

C. Location

There are no field studies to be conducted. Past studies, on which publications will be based, were conducted in Prince William Sound, Kenai/Cook Inlet, and Kodiak/Alaska Peninsula.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The projects are based on data gathered throughout the damage assessment and restoration phases of the *Exxon Valdez* Oil Spill studies funded by the Trustees. Past work has been presented at various public meetings sponsored by the council. It is anticipated that manuscripts produced will be the basis of future presentations at Trustee sponsored restoration workshops.

One of the manuscripts that is to be produced as part of this project, "Comparison of Study Designs for Assessment of Shoreline Impacts of the *Exxon Valdez* Oil Spill" will critique study designs utilized by the Trustee sponsored work, studies sponsored by NOAA, and studies by Exxon. An obvious shortcoming of all of these works is the failure to address subsistence issues, and the failure to utilize traditional ecological knowledge in the study design. A discussion of how these shortcomings might be addressed in future studies will be developed in consultation with the Oil Spill Restoration Office, and will be included as part of the manuscript.

PROJECT DESIGN

A. Objectives

The objective of the proposed study is to produce a minimum of 8 manuscripts for publication in the peer reviewed scientific literature. Six are slated for completion in FY 1998. This proposal requests funding for additional manuscripts to be submitted in FY99.

B. Methods

The manuscripts will be prepared by a team of scientists who have been directly involved in the coastal habitat studies funded by the Trustees. The work will be coordinated by Coastal Resources Associates, Inc. (CRA). Dr. Thomas Dean, President of CRA will serve as project leader. Key individuals in the Coastal Habitat Injury Assessment program will serve as authors of manuscripts to be prepared. These will include Drs. Ray Highsmith and Mike Stekoll of the University of Alaska. Dr. Dean will also serve as a lead author, and will be assisted by Dr. Larry Deysher of CRA who has had extensive involvement in the CHIA program.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

This proposal is being submitted under BAA by Coastal Resources Associates, Inc. However, it is anticipated that a portion of the funding will be directed to the University of Alaska, with contract administration for that portion of the contract conducted by Alaska Department of Fish and Game.

SCHEDULE

A. Measurable Project Tasks for FY 99 (October 1, 1998 - September 30, 1999)

A total of two manuscripts will be prepared for publication during FY99. A description of these is given under "Publications and Reports" below.

B. Project Milestones and Endpoints

All manuscripts slated for preparation in FY99 will be in draft form and available for internal review by March 31, 1999. At that time, a progress report will be submitted to the Trustees that includes the draft manuscripts. All manuscripts will be submitted by April 30, 1998. The schedule for publication will depend on the length of the review period, and on the extent of revisions (if any) required. It is anticipated that all manuscripts will be ready for final acceptance by August 1999.

C. Completion Date

It is anticipated that all ten manuscripts proposed will be submitted and accepted by September 1999. Some carry over of funds may be required to cover page charges incurred in FY00.

PUBLICATIONS AND REPORTS

It is anticipated that a minimum of eight manuscripts will be produced. Six of these are slated for submission in FY98, with an additional 2 proposed for FY99. A listing of anticipated authors, titles, journals selected for submission, and a brief description of the content of each manuscript follows. For manuscripts to be submitted in FY 1998, an assessment of the progress made toward publication is included.

Manuscripts to be prepared in FY 1998

1. Comparison of Study Designs for Assessment of Shoreline Impacts of the *Exxon Valdez* Oil Spill

Proposed Authors: Lyman L. McDonald, Wallace P. Erickson, M. Dale Strickland, and Charles Peterson. (Order to be determined by relative contribution and amount written)

Possible Journals: Marine Pollution Bulletin or Oecologica

This manuscript will contrast the design of the Coastal Habitat Injury Assessment (Highsmith *et al.* 1996, Jewett *et al.* 1995, McDonald *et al.* 1995, Stekoll et al 1996) to study designs used in assessment of shoreline impacts of the spill by Exxon supported scientists (Page *et al.* 1995) and NOAA scientists (Mearns 1996, Houghton *et al.* 1996). The objectives of these studies will be contrasted and the designs will be evaluated in terms of how well project objectives were met, the

relative ability of each design to quantify impacts of the Exxon spill, and the relative strengths and weaknesses of each design. The role of the following will be assessed in each of the studies:

1) random selection of study sites,
2) subjectively selected study sites,
3) interspersion of study sites,
4) definition and selection of reference sites,
5) levels of statistical inference,
6) power to detect important ecological effects (and specifically trade offs one must make with respect to power and ability to make broader statistical inferences),
6) the role of experiments (as contrasted to surveys) in injury assessment,
7) statistical analyses, and
8) definitions for recovery.

Progress: Dr. McDonald has outlined this manuscript and has solicited comments from co-authors regarding its content.

2. *Fucus* and the *Exxon Valdez* Oil Spill: Injury and Recovery

Proposed Authors: Michael S. Stekoll, Lawrence E. Deysher, and Mandy R. Lindeberg

Possible Journals: Marine Ecology Progress Series or Marine Environmental Research

Analysis of injury to *Fucus* will be presented for all areas (Prince William Sound, Kenai/Lower Cook Inlet, and Kodiak/Alaskan Peninsula) and habitats (Sheltered Rocky, Exposed Rocky, Coarse Textured, and Estuarine) for the period 1991-1994. The focus will be on *Fucus gardneri* populations (abundance, biomass. reproductive state, injury to plants, extent of fouling, percent cover), and will contrast the patterns observed at the three areas representing different levels of oiling and cleanup, and different physical regimes. The discussion will draw on previously published studies of experimental evaluations on the recovery and recolonization of *Fucus* in Herring Bay (Stekoll and Deysher 1996, Van Tamlen and Stekoll 1995, 1996; and Van Tamlen *et al.* 1997) to help explain differences in patterns observed in different areas and habitats.

Progress: Dr. Stekoll has produced a draft manuscript and it is currently being reviewed by co-authors. Dr. Stekoll is planning on revising this manuscript and submitting it for publication by August 1998.

3. Injury to, and Recovery of Rocky Intertidal Communities in Prince William Sound Following the *Exxon Valdez* Oil Spill

Proposed Authors: Raymond C. Highsmith, Thomas A. Dean, and Susan M. Saupe.

Possible Journals: Marine Ecology Progress Series or Marine Environmental Research

This manuscript will assess injury to dominant taxa of intertidal plants and animals in Prince William Sound in sheltered rocky, exposed rocky, and coarse textured habitats. The paper will utilize data from a broad geographic examination of injury based on studies carried out throughout the Sound (Coastal Habitat Injury Assessment Studies), and from a longer time series of observations in Herring Bay (Herring Bay Population Dynamics Studies) to evaluate injury and recovery of dominant taxa (*Fucus*, ephemeral algae, barnacles, limpets, mussels and littorines). We will examine how the Herring Bay and CHIA data correlate with one another and attempt to use the Herring Bay data to infer mechanisms of impact and processes of recovery for communities throughout the Sound. For example, the paper will related algal species composition and abundance following the spill and potential relationships to subsequent invertebrate distributions, and vice versa.

Progress: The has been no progress on this manuscript.

4. Factors Limiting Recovery of Limpet Populations following the *Exxon Valdez* Oil Spill

Proposed Authors: Thomas A. Dean, Anthony J. Hooten, and R. Highsmith. (Order to be determined by relative contribution and amount written)

Possible Journals: Marine Ecology Progress Series or Marine Environmental Research

This paper will focus on limpets. The evidence for injury (based mostly on CHIA data), and recovery (based mostly on the Herring Bay population dynamics data) will be reviewed. The bulk of the paper will examine experimental data from fencing and caging experiments on the effects of oiled substrates as well as other factors (e.g. algal density and limpet density) on the recovery process. A preliminary examination of the data suggest that limpets (especially *T. persona* in the upper intertidal) were severely injured, that most populations perhaps recovered by 1993 or 1994, and that oiled substrates apparently did not inhibit recovery. Experimental data indicate that limpets graze on algae and provide a mechanism that might explain why cover by filamentous algae increased following the spill. Experimental data also suggest some interesting biology regarding density dependence in limpets, and the potential effects of predators on survival of limpets. Population dynamics data indicate that there was a large increase in the abundance of limpets at both oiled and control sites in Herring Bay between 1990 and 1994. We can speculate that this might have been natural temporal variation, or a result of a release from predation pressure throughout Herring Bay because of an oil related reduction in oystercatchers, harlequin ducks and other potential predators.

Progress: Dr. Dean has obtained databases with algal and invertebrate data necessary for manuscript preparation from the University of Alaska and Mr. Andy Hooten. Some preliminary analyses have been conducted, especially with respect to extracting needed algal data from existing coastal habitat injury assessment databases.

5. Effects of the *Exxon Valdez* Oil Spill and Non-Anthropogenic Factors on the Distribution and Abundance of Nearshore Benthic Fishes in Prince William Sound, Alaska

Proposed Authors: T.A. Dean, L. Haldorson, D. Laur, and S. Jewett. (Order to be determined by relative contribution and amount written)

Possible Journals: Fisheries Bulletin, Environmental Biology of Fishes

This paper will examine the factors affecting the distribution and abundance of nearshore benthic fishes including a variety of habitat characteristics (vegetation type, slope, substrate type, exposure) as well as oiling of adjacent shorelines. We will examine community response (MDS and PCA analysis) as well as responses of dominant taxa (using non-linear models and/or PCA analysis). A previous publication (Laur and Haldorson 1996) examined only the differences between fish abundance at oiled and control sites, by species and habitat. This manuscript will present a more community based approach, that also examines the influence of factors other than oil on distribution and abundance. Data are from the 1990 subtidal surveys, with a few other data from eelgrass habitat surveys in subsequent years . A draft of this manuscript is in preparation.

Progress: An outline has been produced and analysis of fish community data has been initiated. Initial multivariate analysis (MDS and principal component analyses) were completed, and further analyses are underway. It is anticipated that a draft manuscript will be prepared by May 1998.

6. Impacts of the *Exxon Valdez* Oil Spill on Benthic Communities in Eelgrass Habitats

Proposed Authors: S.J. Jewett, T.A. Dean, A. Blanchard, and R.O. Smith.

Possible Journals: Marine Ecology Progress Series

Examination of impacts to subtidal benthic infauna and small epifauna based on subtidal studies. This is a manuscript that comes directly from sections of the report of Jewett and Dean (1996) on eelgrass communities that deal with dredge sample data.

Progress: This manuscript was submitted to Marine Ecology Progress Series in January 1998.

Manuscripts to be prepared in FY99

7. Algal Community Function Following the *Exxon Valdez* Oil Spill

Proposed Authors: Michael S. Stekoll, Lawrence E. Deysher, and M.R. Lindeberg.

Possible Journals: Marine Ecology Progress Series or Marine Environmental Research

An examination of community level responses following the EVOS, based on algal data from Coastal Habitat Injury Assessment studies conducted in Prince William Sound, Kenai/Cook Inlet, and Kodiak/Alaskan Peninsula. Community similarity (MDS), diversity, functional group analysis

(e.g. leafy blades, filamentous algae), higher order taxa analysis (red vs. green algae), and life history groupings (annuals vs. perennials, widely dispersed vs. not so widely dispersed, etc.) will be presented.

8. A Summary of Impacts of the *Exxon Valdez* Oil Spill on Nearshore Subtidal Communities

Proposed Authors: T.A. Dean and S.J. Jewett.

Possible Journals: Ecological Applications, Annual Reviews of Ecology and Systematics

A summary of available information on the injury and recovery of subtidal communities including (but not necessarily limited to) studies of impacts and recovery of subtidal communities (Armstrong *et al.* 1995; Dean *et al.* 1996a, 1996b; Jewett and Dean 1997; Jewett et al 1995, 1996; Laur and Haldorson 1996); hydrocarbon data (Bence and Burns 1995; Carlson and Kvenvolden 1996; O'Clair *et al.*, 1996; Page *et al.* 1995; Short and Babcock 1996; Short *et al.* 1996a, 1996b; Wolfe *et al.* 1994); bacteria data (Braddock and Richter 1994; Braddock *et al.* 1995, 1996); toxicity data (Armstrong *et al.* 1995; Wolfe *et al.* 1996), and biomarker data in subtidal fishes (Armstrong *et al.* 1995; Collier *et al.* 1996). Salmon and herring data will be not be reviewed. This manuscript is in preparation.

PROFESSIONAL CONFERENCES

No funding is being requested for attendance at professional conferences in FY99.

NORMAL AGENCY MANAGEMENT

This project has been developed through collaboration of private sector and University of Alaska scientists. None of the proposers have management responsibility. However, it is anticipated that publications produced will be widely utilized in future management decisions.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The scientists involved in the preparation of manuscripts have worked collaboratively in previous Trustee funded investigations of injury and recovery in coastal habitats. Authors will serve as internal reviewers of each of the manuscripts while these manuscripts are in preparation.

Several of the authors are also participants in other large ecosystem studies funded by the Trustees. Thomas Dean and Stephen Jewett are principal investigators for the Nearshore Invertebrate Predator Project and Lyman McDonald serves as consulting statistician for both the Nearshore Vertebrate Predator and APEX projects. The APEX and especially the Nearshore Vertebrate Predator Project have large components that deal with coastal habitats, and new findings produced by these studies will be considered when preparing manuscripts. It is also

anticipated that information presented in the manuscripts, along with the information gained in ongoing research and monitoring efforts, will be integrated and utilized in developing future monitoring plans for coastal habitats.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

A review of impacts on intertidal communities that was originally proposed for inclusion in the FY 1999 budget is currently being developed under separate contract to Dr. Charles Peterson, and is not included in this renewal proposal. As a result, the budget for FY 1999 is less than originally anticipated.

PROPOSED PRINCIPAL INVESTIGATORS

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BIOGRAPHICAL SKETCHES FOR PRINCIPAL INVESTIGATORS

Dr. Thomas A. Dean is President of the ecological consulting firm Coastal Resources Associates, Inc. (CRA) in Vista, CA. Dr. Dean has over 20 years of experience in the study of nearshore ecosystems, and has authored over 20 publications, including several dealing with impacts of the *Exxon Valdez* oil spill on subtidal populations of plants and animals. He has extensive experience in long-term monitoring studies, and has played a major role in both intertidal and subtidal EVOS investigations since 1989.

Dr. Michael Stekoll is a Professor of Biology at the University of Alaska, Southeast, and the School of Fisheries and Ocean Sciences at the University of Alaska, Fairbanks. He has served as the Principal Investigator for the coastal habitat injury assessment (CHIA) study and Herring Bay experimental and monitoring studies that examined the impacts of the EVOS on intertidal and subtidal algae. His specialties include studies of *Fucus, Macrocystis*, and other seaweeds in Alaska.

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Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the *Exxon Valdez* Oil Spill: Preparation of Manuscripts for Publication - Submitted Under BAA

Project Number: 98325

Budget Summary for FY99

Coastal Resources Associates, Inc. (BAA-NOAA)	$ 23,848
University of Alaska (AK Fish & Game)	$ 17,344
Total	$ 41,192

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel	$13,055.0	$13,055.0
Travel	$0.0	$0.0
Contractual	$0.0	$0.0
Commodities	$1,000.0	$1,000.0
Equipment	$0.0	$0.0
Subtotal	$14,055.0	$14,055.0
Indirect	$3,289.0	$3,289.0
Project Total	$17,344.0	$17,344.0
Full-time Equivalents (FTE)	1.50	1.50
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

Estimated FY 2000	Estimated FY 2001	Estimated FY 2002	Estimated FY 2003
$0.0			

Dollar amounts are shown in thousands of dollars.

Comments:

1999

Prepared:

Project Number: 99325
Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the *Exxon Valdez* Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"
Name: University of Alaska, Southeast

FORM 4A
Non-Trustee
SUMMARY

4/13/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FY 1999
Stekoll, Mike	Lead Author		1.5	$8,703	0.0	$13,055
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		1.50	$8,703	0.0	
					Personnel Total	$13,055

Travel Costs:		Ticket	Round	Total	Daily	Proposed
Description		Price	Trips	Days	Per Diem	FY 1999
None						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

1999

Prepared:

Project Number:
Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the Exxon Valdez Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"
Name: University of Alaska, Southeast

FORM 4B
Personnel
& Travel
DETAIL

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
None	
Contractual Total	$0.0

Commodities Costs:	Proposed FY 1999
Description	
Office and computer supplies	$500
Page charges - manuscript	$500
Commodities Total	$1,000

1999

Prepared:

Project Number:
Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the Exxon Valdez Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"
Name: University of Alaska, Southeast

FORM 4B
Contractual & Commodities
DETAIL

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
None			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	

1999

Prepared:

Project Number:
Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the Exxon Valdez Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"
Name: University of Alaska, Southeast

FORM 4B
Equipment
DETAIL

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel	$14,662	$11,689
Travel	$0	$820
Contractual	$1,400	$0
Commodities	$1,740	$800
Equipment	$0	$0
Subtotal	$17,802	$13,309
Indirect	$13,318	$10,539
Project Total	$31,120	$23,848
Full-time Equivalents (FTE)	2.2	1.60
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

Estimated FY 2000	Estimated FY 2001	Estimated FY 2002	Estimated FY 2003
$800	$0	$0	$0

Dollar amounts are shown in thousands of dollars.

Comments: 1. Contractual changes are as follows:

1. CRA, Inc. Indirect Rates calculated as follows: Overhead = 59.5% of salaries and fringe.
General Administrative = 12.085% of total direct costs,.
Fee = 5% of total direct and indirect

1999

Prepared:

Project Number: 98325

Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the Exxon Valdez Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"

Name: Coastal Resources Associates, Inc.

FORM 4A
Non-Trustee
SUMMARY

4/13/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Personnel Costs:			Months	Monthly		Proposed
	Name	Position Description	Budgeted	Costs	Overtime	FY 1999
	Dean, Thomas A.	Project Coordinator-Lead Author	1.00	$7,984	0.0	7,984
	Deysher, Lawrence E.	Co-author	0.35	$7,984	0.0	2,794
	Jung, Dennis	Graphical/Production Assistant	0.25	$3,642	0.0	911
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	1.6	$19,610	0.0	
					Personnel Total	$11,689

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 1999
						0.0
	One round trip					0.0
	San Diego to Anchorage	$500	1	4	$80	$820
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$820

1999

Prepared:

Project Number: 98325

Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the Exxon Valdez Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"

Name: Coastal Resources Associates, Inc.

FORM 4B
Personnel
& Travel
DETAIL

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Contractual Costs:		Proposed FY 1999
Description		
	Contractual Total	$0

Commodities Costs:		Proposed FY 1999
Description		
Page Charges	2 journal articles	$800
	Commodities Total	$800

1999

Prepared:

Project Number: 98325
Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the Exxon Valdez Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"
Name: Coastal Resources Associates, Inc.

FORM 4B
Contractual & Commodities DETAIL

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
None			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	

1999

Prepared:

Project Number: 98325
Project Title: Assessment of Injury to Intertidal and Nearshore Subtidal Communities Following the Exxon Valdez Oil Spill: Preparation of Manuscripts for Publication "Submitted under BAA"
Name: Coastal Resources Associates, Inc.

FORM 4B
Equipment
DETAIL

Project Title:	**Pigeon Guillemot Restoration Research at the Alaska SeaLife Center**
Project Number:	99327
Restoration Category:	Research (continuing)
Proposed By:	Oregon State University (PI - Daniel D. Roby)
Lead Trustee Agency:	DOI
Duration:	2nd year, 4-year project
Cost FY 99:	$147,697
Cost FY 00:	$156,701
Geographic Area:	Alaska SeaLife Center, and adjoining areas of Resurrection Bay
Injured Resource/Service:	Pigeon Guillemots, other injured seabird resources

ABSTRACT

This study tests the feasibility of direct restoration techniques for Pigeon Guillemots (e.g., installation of artificial nest sites, use of social attractants, captive propagation and release), a seabird species that was injured by the EVOS and has failed to recover. While raising young guillemots in captivity it will also be possible to conduct controlled experiments crucial to two other restoration objectives: (1) development of nondestructive biomarkers of petroleum hydrocarbon contamination in seabirds, and (2) understanding how dietary factors (prey species composition, prey size, lipid content, feeding frequency) constrain growth, development, and condition at fledging in guillemots and other fish-eating seabirds.

STUDY HISTORY

This study is beginning its first field season in May 1998. Considerable progress has been made in setting up the Research Work Order from USGS-BRD to Oregon State University that will fund this project, selecting a graduate student for the project, designing and constructing artificial nest sites, exploration of potential sites for collecting guillemot eggs and young chicks, and obtaining the necessary permits (NEPA, Scientific Collecting) and approvals (IACUC) to conduct the work.

INTRODUCTION

The Pigeon Guillemot (*Cepphus columba*) population in Prince William Sound has failed to recover from declines that occurred both before and after the *Exxon Valdez* Oil Spill (EVOS). Post-spill studies of Pigeon Guillemot reproductive success have identified three primary factors preventing recovery:
1) In Prince William Sound (Naked and Jackpot islands) and Kachemak Bay, predation on eggs and chicks was a major source of nesting failure (Hayes 1996, Prichard 1997).
2) There has been a decline in the proportion of sand lance in the diet at some guillemot colonies in Prince William Sound (e.g., Naked Island), and the proportion of high-quality schooling forage fish in the diet seems to be a key factor in guillemot reproduction. The Alaska Predator Ecosystem Experiment (APEX) Project components F (Factors Limiting Pigeon Guillemot Recovery), G (Seabird Energetics), and M (Seabird/Forage Fish Studies in Lower Cook Inlet) are investigating the relationship between a lack of recovery and the availability and quality of forage fish. A decline in availability of high-lipid forage fishes (sand lance, herring, capelin) in the last two decades may be responsible for lower growth rates, fledging weights, post-fledging survival, and adult recruitment.
3) The Nearshore Vertebrate Predator (NVP) Project (River Otter and Pigeon Guillemot component) is testing the hypothesis that exposure to residual oil from the spill continues to limit recovery of Pigeon Guillemots. Pigeon Guillemots feed on a diversity of nearshore demersal fishes and schooling forage fish that use the substrate to avoid predators (e.g., sand lance), prey that were likely injured by EVOS. The approach of the NVP study is to measure certain biomarkers in blood and compare biomarker levels in nestlings from oiled and nonoiled areas. These blood biomarkers still need to be calibrated to known doses of weathered Prudhoe Bay Crude Oil (PBCO) in a controlled, laboratory setting.

The proposed research will be conducted at the Alaska SeaLife Center in Seward and will address all three of the above limiting factors. Experimental studies using captive subjects will be integrated with raising Pigeon Guillemot nestlings in captivity in order to establish free-ranging guillemot breeding colonies in the vicinity of the SeaLife Center. Predator-free nest sites will be built in the vicinity of the SeaLife Center and, in association with the use of decoys and audio playbacks of guillemot calls, will be used to attract and recruit prospecting guillemots to breed. Guillemot populations are frequently nest-site limited (Storer 1952) and Pigeon Guillemots readily breed in anthropogenic structures, such as docks and breakwalls, at many locations throughout the species' range. Like most seabirds, guillemots are philopatric to their natal location, and the cohorts that are raised in captivity at the SeaLife Center and released there can be expected to return and attempt to breed at the surrounding area. Although guillemots only rarely breed before three years of age, prospecting 2-year-olds that are raised in the first year of this three-year study can be expected to visit the SeaLife Center in the last year of this study. For the first two years of the study, immigration from nearby natural colonies will provide recruits to the colonies of free-ranging guillemots that we seek to establish near the SeaLife Center.

Providing artificial nest sites has the potential to restore guillemot populations through enhancing both local recruitment of adults and nesting success. Our success in recruiting prospecting adult guillemots to use artificial nest sites and the proportions of captive-reared and immigrant guillemots that utilize artificial nest sites will allow us to test the feasibility of this direct restoration technique for enhancing recovery of guillemot populations in the EVOS area.

The proposed work is intended to result in the establishment of breeding colonies of free-ranging Pigeon Guillemots near the SeaLife Center. By banding immigrants to the colony and young that are raised and released at the SeaLife Center, we can establish a breeding colony comprised of known-age individuals whose breeding history is known. Accessibility of nest sites can be a major obstacle for studies of factors influencing nesting success and demographics of guillemots, and artificial nests sites can provide investigators with unique opportunities. A dockside Black-legged Kittiwake colony in Great Britain has been studied for the past 30 years and provided most of what is known about that species in the northeastern Atlantic (i.e., Coulson 1988). Establishment of Pigeon Guillemot colonies near the SeaLife Center has the potential of providing a similar resource, in addition to providing opportunities for integration with ASLC's public education program.

Besides providing recruits for the breeding colony of free-ranging guillemots to be established at ASLC, raising chicks in captivity will also provide the opportunity to conduct controlled experiments that are relevant to two major issues in Pigeon Guillemot restoration: (1) the effect of prey type, size, quality, and frequency of delivery on nestling growth rates and condition of young at fledging and (2) the utility of biomarkers in blood and excreta as indicators of exposure to crude oil and other environmental contaminants. Research on these two topics can best be conducted using captive subjects whose environment and diet can be carefully controlled to avoid confounding variables so common in natural populations. In the first year of this study (1998), chicks will be raised on different diet regimes to determine the effects of the proportion of schooling forage fishes (sand lance, capelin, herring) vs. nearshore demersal fishes (gunnels, pricklebacks, sculpins) on growth rates. In the subsequent two years of the study (1999 & 2000), controlled feeding experiments will be conducted that are designed to reveal the tradeoffs inherent in meal size, meal frequency, and meal quality (energy density) as they influence nestling growth performance. The results from this study will complement continuing studies on the role of diet for productivity of nesting guillemots that are part of the APEX Project.

In the second and third years of the study, some chicks that are raised in captivity will be fed small, sublethal doses of weathered Prudhoe Bay crude oil (PBCO). Subsequent to dosing, samples of blood and excreta will be collected at prescribed intervals for measurement of biomarkers of health status. These results will allow us to define the dose-response relationship between ingested PBCO and each biomarker of exposure. Such results are essential for evaluating the efficacy of particular biomarkers and the utility of these biomarkers for assessing the exposure of free-ranging guillemots to oil.

Of particular value for interpretation of the results of captive feeding trials and crude oil dose-response experiments will be the subsequent release of these subjects and measurements of their return rates in subsequent years. Although it can not be assumed that all young guillemots that are fledged from the ASLC and survive to breeding age will return to breed near ASLC, the return rates of nestlings raised on various diets, plus return rates of oil-dosed and control nestlings, will provide valuable information on the long term effects of prey composition and oil exposure for guillemot fitness.

NEED FOR THE PROJECT

A. Statement of Problem

In the last two decades the Pigeon Guillemot population in Prince William Sound has declined from 15,000 to 5,000 individuals (Laing and Klosiewski 1993). While this decline apparently began prior to the EVOS, an estimated 10-15% of the population in the spill area died as a direct result of the spill. Post-spill censuses have not detected an increase in numbers, suggesting no appreciable recovery has occurred in the aftermath of the spill. Reasons for the lack of recovery are unclear, but may be related to changes in prey resource availability, continuing exposure of

guillemots or their prey to oil, or nesting failure due to predation on guillemot eggs and/or nestlings.

Predation on Pigeon Guillemot eggs and chicks was apparently minimal before EVOS, but post-spill studies have frequently recorded high levels of predation from river otters and mink (Hayes 1995). High predation rates could be reducing production of local birds, increasing breeding dispersal (lack of fidelity to a previously used nest site or location) of established breeders, and decreasing the immigration of guillemots from other colonies. While Pigeon Guillemots typically have high fidelity to their breeding site, disturbance and lack of breeding success can increase the rate and distance of breeding dispersal. Populations suffering high levels of disturbance, such as persistent nesting failure due to terrestrial predators, will decline due to a lack of production of new recruits, dispersal of breeding birds, and/or decreased immigration.

Two ongoing EVOS projects have identified potential reasons for a lack of recovery by Pigeon Guillemots in the EVOS area. The APEX Project has identified a major shift in the nearshore ecosystem that has apparently resulted in fewer schooling fish, particularly sand lance (*Ammodytes hexapterus*) fed to chicks (Oakley and Kuletz 1994, Golet et al. unpubl. ms.). Pre-spill studies found sand lance, a nearshore schooling fish with a high lipid content, to be the dominant prey returned to chicks. Post-spill studies have found gadids and nearshore demersal fish to constitute the majority of the diet. The NVP project has attempted to determine if blood biomarkers can be used to monitor level of exposure to oil and if blood from individuals in wild populations currently indicates exposure to oil is occurring. Both of these projects have examined wild populations that are exposed to numerous sources of variability that confound the examination of factors affecting chick growth or blood biomarkers.

This study is relevant to EVOS Restoration Work because it is designed to develop direct restoration techniques for Pigeon Guillemots, a species injured by the spill that is failing to recover. Techniques developed during this study will be relevant to restoration of other alcid species. Also, dose-response experiments with guillemot nestlings fed small, sublethal amounts of weathered Prudhoe Bay crude oil will provide crucial validation and calibration results for interpretation of on-going studies of biomarkers as indicators of crude oil exposure. Experimental studies with captive-reared guillemots will also provide a better understanding of how shifts in the diet of guillemots and other seabirds breeding in EVOS area affects growth, development, fledging condition, and, ultimately, fitness. By monitoring the growth and development of nestlings raised on controlled rations, the relative nutritional quality of various prey can be assessed. Also, fitness tradeoffs between prey size/quality and provisioning rate can be assessed through monitoring of subsequent survival in the wild of captive-reared chicks. Understanding the constraints imposed on guillemots by diet composition, oil exposure, and nest site quality will be crucial for designing management initiatives to enhance productivity in this and other seabird species that are failing to recover from EVOS.

B. Rationale/Link to Restoration

Artificial nest sites have the potential to increase the size of both guillemot breeding colonies and populations. A Black Guillemot colony in arctic Alaska increased from 10 to 225 pairs in 17 years through provision of artificial nest sites (Divoky et al. 1974 and in prep.). In Washington State 27% of the 33 Pigeon Guillemot colonies are in piers or other anthropogenic structures (Speich and Wahl 1989). Establishment of a Pigeon Guillemot colony near the Alaska SeaLife Center will demonstrate the utility of direct restoration in assisting the recovery of Pigeon Guillemot populations in the northern Gulf of Alaska. If artificial nest sites are successful in attracting breeding adults and if successful reproduction ensues, artificial nest sites can be used in Prince William Sound to enhance productivity, recruitment, and immigration, all of which will facilitate recovery. Clusters of artificial nest sites similar to those at the ASLC can be installed near natural colonies that suffer from chronically high nest predation rates. Nests could be placed on pilings or "dolphins" constructed specifically for colony development.

Aside from providing prototypes for artificial colonies in other parts of the EVOS area, a breeding colony of free-ranging guillemots at the ASLC will allow investigators to conduct research on Pigeon Guillemots that would not be possible at natural colonies. Loss of eggs or chicks to predation has been a major source of nest failure in post-spill studies of Pigeon Guillemots in Prince William Sound (Hayes 1995). In addition, marked adults and returning young will allow an examination of demographics that has not been possible in Prince William Sound studies. A lack of recovery could be due to demographic parameters (e.g., adult survival, subadult survival, immigration/emigration rates) not evident in studies of nesting success or colony censuses. Guillemot demographics are much more easily studied at a colony of artificial nest sites where the banding of chicks and adults entails far fewer problems than at natural colonies. Should the proposed work result in the deployment and use of artificial nest sites in Prince William Sound, investigators will be able to obtain demographic information for that area that could explain the lack of recovery of local populations.

While the proposed colonies of Pigeon Guillemots to be established near the ASLC will have the benefit of captive-reared chicks returning to their natal location and assisting in establishment of the colony, immigration is obviously the source of adults founding new colonies. Immigrants can also be the primary source of recruits to established and expanding colonies (Petersen 1981). Unlike many seabirds, guillemots are semi-colonial and able to breed as single pairs as well as colonially. Prospecting guillemots can be expected to search for nesting opportunities more extensively than more colonial seabirds, which require minimum numbers of conspecifics for successful breeding. Nest sites at ASLC are likely to attract nonbreeding prospectors from the approximately 100 pairs of Pigeon Guillemots breeding between Aialik Cape and Cape Resurrection (Nishimoto and Rice 1987), as well as more distant colonies. An expanding colony of Black Guillemots in arctic Alaska drew most of its recruits from colonies more than 400 km distant (Divoky, in prep.).

A Pigeon Guillemot colony could also have the potential of attracting other seabird species to nest in the area of ASLC. Some of these other species may also be recruited by providing nest sites. A Black Guillemot breeding colony that utilized artificial nest sites in arctic Alaska also attracted Horned Puffins (*Fratercula corniculata*), some of which used the artificial nest sites (Divoky 1982 and unpubl.).

The research component of this study will allow evaluation and validation of the use of nondestructive biomarkers (in blood and excreta) to assess the health status of individual guillemots and potential exposure to petroleum hydrocarbons. There is evidence that certain acute phase proteins (i.e., haptoglobin) in blood and porphyrins in excreta are induced by ingestion of sublethal doses of weathered crude oil (Prichard et al. 1997). The results of a dose-response experiment with wild guillemot nestlings in their natural nest sites, however, were ambiguous because of among-site variability in baseline values for biomarkers (Prichard et al. 1997). Also, guillemot nestlings were fed small doses (0.05-0.2 ml) of highly weathered PBCO in that study; the doses were not sufficient to cause a significant decline in growth rates of nestlings. Finally, blood samples for measuring biomarker levels were not collected until five days post-dosing, when any induction of an acute phase response had likely passed. While the use of blood and fecal biomarkers for monitoring oil exposure and general population health of guillemots is promising, more research under controlled, captive conditions is required to validate the techniques and provide a sound basis for interpretation of results from wild guillemots.

There is a definite need for information on the relationship between diet and reproductive success for Pigeon Guillemots, a seabird species that is failing to recover from EVOS at an acceptable rate (1994 *Exxon Valdez* Oil Spill Restoration Plan). Guillemots are the most neritic members of the marine bird family Alcidae (i.e., murres, puffins, and auks), and like the other members of the family, capture prey during pursuit-dives. Pigeon Guillemots prey on a wide variety of fishes, including schooling forage fish (e.g., sand lance, herring, pollock) and subtidal/nearshore demersal fish (e.g., blennies, sculpins; Drent 1965, Kuletz 1983). There is

strong evidence of a major shift in diet composition of guillemot pairs breeding at Naked Island. Sand lance were the predominant prey fed to young in the late 1970s (Kuletz 1983), but currently sand lance is a minor component of the diet (G. Golet, unpubl. ms.). In contrast, guillemots breeding in Kachemak Bay continue to provision their young predominately with sand lance, and sand lance is particularly prevalent in the diet at sites that support high densities of breeding pairs (Prichard 1997). Also, young of breeding pairs that provision their nestlings with mostly sand lance have higher growth rates (Prichard 1997, Golet et al. unpubl. ms.). Jackpot Island in southwestern Prince William Sound supports the highest nesting densities of guillemots anywhere in the Sound and growth rates of nestlings are correspondingly high. The high availability of juvenile herring to guillemots nesting at Jackpot Island may be responsible for both the high nesting density and high growth rates. Thus availability of high-quality schooling forage fishes (herring, sand lance) may be crucial for maintaining high nesting densities of highly productive guillemots.

C. Location

Pigeon Guillemot nestlings will be raised in captivity at the Alaska SeaLife Center in Seward. Guillemot nestlings will be hatched from eggs obtained from source colonies on the Kenai Peninsula or at other appropriate northern Gulf of Alaska colonies. Eggs that fail to hatch will be replaced with young nestlings (< 7 days post-hatch) collected from other colonies. Impact of these collections on the productivity of source colonies will be minimal as eggs lost during the first half of incubation are usually replaced during renesting and the majority of guillemot nesting attempts in the NGOA fail to produce fledglings because of high nest predation rates. Most of the captive-reared fledglings will be banded and released at ASLC to assist in efforts to establish local breeding colonies of free-ranging guillemots near ASLC. Artificial nest sites will be constructed near ASLC on an adjacent breakwall and other sites to enhance the prospects for colony establishment. Colonies in Resurrection Bay that may serve as sources of immigrants or may recruit captive-reared guillemots will be censused and checked for banded adults annually during the three years of the project. The information obtained from this project will benefit Pigeon Guillemot populations in the Gulf of Alaska, especially Prince William Sound. An understanding of the affect of prey type on chick growth will help explain the role of ecosystem shifts in continuing declines of Pigeon Guillemot populations. Assessing the utility of blood biomarkers for detecting and quantifying exposure to crude oil will benefit efforts to monitor the health status of Pigeon Guillemot populations throughout the spill zone without resort to lethal sampling procedures.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

All research will be conducted at the Alaska SeaLife Center, which will allow the community in and around Seward to observe progress in the establishment of guillemot colonies in both artificial and natural nest sites. Wild breeding colonies near ASLC have the potential for involving science classes from local schools. The location of colonies will potentially permit easy viewing by the public and allow science teachers to use the colony for instruction about seabird breeding biology and restoration. Science classes could conduct observations on the occurrence and activities of prospecting and breeding guillemots. Some of these (timing of arrival in the spring and sightings of color banded adults) could provide important information for the period when the investigators are not in Seward. Local science teachers can receive annual summaries of information about local colonies (e.g., timing of clutch initiation, breeding success) that can provide the basis for lessons on regional climate change and annual variability in the marine environment. The Seaquest Program of the Chugach School System would be a logical avenue for presenting this material to students.

PROJECT DESIGN

A. Objectives

This research project has three primary objectives listed below. During the second year of the project (CY 99), the emphasis will be on achieving all three objectives.

1. Determine the feasibility of using direct techniques for restoration of Pigeon Guillemots, including:
   a) providing artificial nest sites
   b) use of social attraction, such as decoys and playbacks of vocalizations
   c) release of captive-reared young

2. Determine the response of particular biomarkers of crude oil exposure (acute phase proteins, plasma sodium, fecal porphyrins) to variables of exposure in guillemot nestlings, and the survival of exposed nestlings post-fledging. Exposure variables that will be examined include:
   a) dose of ingested oil
   b) degree of weathering of ingested oil
   c) time since ingestion of dose
   d) frequency of exposure

3. Determine the effect of diet variables on growth performance, development, fledging condition, and post-fledging survival of Pigeon Guillemots, including:
   a) types of forage fish consumed, with emphasis on schooling forage fishes vs. nearshore demersal fishes
   b) lipid content of the diet
   c) size of prey items
   d) frequency of prey delivery

B. Methods

The proposed work will test the following three basic hypotheses, which relate to each of the three primary objectives listed above:

Hypothesis 1. Artificial nest sites, decoys, and playbacks of vocalizations can be used to establish new Pigeon Guillemot breeding colonies and enhance breeding success over that experienced at natural colonies using natural nest sites.

Hypothesis 2. Biomarkers from the plasma and excreta of nestling Pigeon Guillemots can be used as indicators of exposure to weathered crude oil in the food supply, and the subsequent survival probabilities of young guillemots post-fledging.

Hypothesis 3. Growth performance, fledgling condition, and post-fledging survival of Pigeon Guillemot nestlings are sensitive to differences in prey type, prey size, feeding frequency, and lipid content of prey.

Methodology employed during the second year of the study (CY 99) will consist of the following:

Objective 1: Testing Feasibility of Direct Restoration Techniques

a. Installation of Artificial Nest Sites and Use of Social Attraction

Pigeon Guillemot nest sites will be constructed and installed at two additional locations in the vicinity of the Alaska SeaLife Center. A minimum of five nest sites and three to five decoys will be placed at each new location. Additional nest sites will be provided at each location if the number of breeding birds and prospecting adults exceeds the number of available nest sites. Design of the artificial nest sites is based on the sites developed by Dr. Divoky for Pigeon Guillemots in Puget Sound, with modifications based on studies of nest site characteristics that

are associated with nesting success in Kachemak Bay (Prichard 1997). Sites will have two entrances with a central nesting cavity. Baffles in the entryways to the nest cavity will prevent avian predators from viewing nest contents. Based on the locations of Pigeon Guillemot nest sites associated with docks and piers, it appears that placing the sites beneath an overhang will increase their attractiveness to guillemots prospecting for nest sites. Sites under an overhang apparently have the advantage of decreased avian predation. Sites will be large enough to accommodate monitoring devices (such as a closed circuit camera, platform scale, or activity monitor) that may be used in future research.

Guillemot decoys will be made from molds produced by Mad River Decoy in Vermont. A CD player with external speakers will be used to play adult Pigeon Guillemot calls from May to mid August. Because prospectors may make recruitment decisions based on local breeding productivity (Boulinier et al. 1996), from late June to late August the calls of chicks in nest sites will also be played during the early morning and evening, when colony attendance can be expected to be highest. Similar combinations of decoys and audio playbacks have been used successfully for other seabird species, including alcids (Kress and Nettleship 1989, Kress 1983), but have never before been used to attract guillemots to nest at new locations.

Guillemots may begin prospecting for nest sites as early as March and nest sites and decoys will be deployed in March 1999. Personnel from this project will not be present at ASLC during most of March and April and staff from ASLC will be asked to make incidental observations of any guillemots associating with the artificial nest sites or decoys during our absence. We will attempt to assure that artificial nest sites and decoy placements are visible from ASLC. We will begin systematic observations of artificial nest sites and decoy sets in early May. Daily observations will be conducted at the times expected to have maximum colony attendance (0200-0900 and 1600-2000 Alaska Daylight Time, high tides). Initially observations will be recorded every 15 minutes on the number of Pigeon Guillemots visible from the roof of ASLC and their distance from artificial nest sites. Once guillemots begin associating with decoys and nest sites, we will conduct detailed observations on the behavior of prospecting birds. The location and activities of prospectors will be recorded during 15-minute periods. Behavioral observations will be similar to those conducted by Preston (1968) on Black Guillemot social behavior. In the initial stages of the study, when the sighting of any guillemots associating with artificial nest sites will be important, we will attempt to use a closed-circuit television camera to monitor activity while project personnel are in the SeaLife Center.

b. Monitoring of Pigeon Guillemot Breeding Biology and Demographics

Should breeding occur in the artificial nest sites in 1999, we will obtain information on the breeding biology of birds using the nest sites. To reduce the chances of nest site abandonment, no adults will be captured during 1998, but if successful breeding takes place in 1998, we will attempt to noose breeding adults for banding in 1999. In 1999 the following breeding parameters will be monitored:

- date of clutch initiation
- egg weight and volume
- egg color and pattern
- date of hatching
- weight at hatching
- hatching success
- growth rate (measured every two-four days)
- fledging weight
- fledging age
- fledging success

The observations on breeding chronology and success can be compared with ongoing field studies of Pigeon Guillemot nesting in Prince William Sound and Kachemak Bay. Additionally

the information on egg size and color can be used in future years to assess the potential of using egg characteristics to measure female survival and recruitment.

During the nestling period we will conduct observations on the prey types delivered to chicks. These observations will determine the taxonomic composition of nestling diets at each nest and collectively. These observations will be compared with diet data collected at natural colonies in Prince William Sound and Kachemak Bay (Golet unpubl. ms., Prichard 1997).

c. Captive-rearing of Chicks

Guillemot eggs will be collected in late May and early June, during the laying period or early in incubation. Eggs will be collected from nests on the Kenai Peninsula or other locations in the northern Gulf of Alaska. Collection will occur as soon as possible after clutch completion. Guillemots frequently relay when a clutch is lost within a few days of clutch completion (Divoky, unpubl.), and taking eggs early in incubation would minimize the impact on productivity of the host colony. Additionally, the sensitivity of embryos to lapses in incubation increases during development, and transporting eggs in the early stages of development should increase hatching success. Eggs will be transported to the ASLC and incubated in a large cabinet incubator operated by ASLC until they hatch or it becomes clear the eggs are infertile or addled. We prefer to collect and transport eggs rather than chicks partly so that all the conditions influencing post-natal growth can be controlled in the lab. However, if hatching success is low or hatchling survival poor, we will substitute guillemot chicks removed from nests shortly after hatching in order to meet target sample sizes for numbers of chicks raised in captivity and released at ASLC. Chicks translocated later in the nestling period display philopatry to the location of hatching, instead of fledging (Serventy 1967, Fisher 1971).

The source colonies for eggs or hatchling guillemots will be primarily on the Kenai Peninsula, and will be selected based on the numbers of breeding pairs at each colony and the accessibility of individual nests. The outer coast of the Kenai peninsula from Port Bainbridge in the east to Port Graham in the west has more than an adequate breeding population of Pigeon Guillemots to support the collections we propose without a detectable impact on existing colonies. We will collect 110 guillemot eggs early in the 1999 breeding season with the goal of successfully hatching 100 chicks and releasing at least 80 captive-reared fledglings into the wild at ASLC. When two-egg clutches are encountered in the field, we will collect both eggs in the clutch in order to enhance the incidence of clutch replacement at source colonies. If hatching success of eggs placed in the incubator is less than 90%, we will collect sufficient young nestlings guillemots to bring the sample of captive-reared chicks up to 100. If two-chick broods are encountered in the field, we will remove only one of the two chicks in order to increase the chances of the other chick successfully fledging. Assuming a level of philopatry similar to that observed for Black Guillemots (Divoky, in prep.), 35% of fledging guillemot chicks should ultimately return to ASLC from the 1999 cohort, providing >28 potential recruits to local breeding colonies. If all surviving captive-reared guillemots recruit at the natal location, a colony of > 40 breeding pairs should be present by 2004, even if the sites do not attract immigrants from other natural colonies before that time.

d. Release of Captive-reared Chicks

Guillemots fledge at night as early as 30 days after hatching, with most fledging after 35 days (Hayes 1995). Fledglings are able to fly at the time of nest departure, are close to adult size, and are independent of parental care after they fledging. When captive-reared chicks reach 32 days of age, they will be moved in their containers to the roof of ASLC. The covers will be removed from the buckets after sunset and chicks provided the opportunity to fledge. To insure that no predation by gulls or other avian predators occurs, project personnel will attend the chicks whenever they are on the roof. Fledglings will be taken to the roof nightly until all have fledged. Fledglings will be banded with a stainless steel U.S. Fish and Wildlife band and a unique

combination of color polyvinyl chloride bands to allow individual identification at a distance. The latter will be sealed with an adhesive to reduce band loss.

e. Assessment of Size and Productivity of Pigeon Guillemot Colonies in Resurrection Bay

A census of guillemot colonies in Resurrection Bay and adjacent areas will facilitate understanding of the conditions contributing to the establishment of artificial colonies near ASLC. Immigration constituted the majority of recruits at a colony of Black Guillemots in arctic Alaska that was enhanced using artificial nest sites, and Pigeon Guillemots fledging from local natural colonies in Resurrection Bay that have yet to breed can be expected to prospect the sites near ASLC. To assess the size of these potential source populations and their annual productivity we will attempt to census as many local colonies as possible and, when possible, determine breeding productivity. We have not budgeted for transportation to these sites but will attempt to visit them on tour boats, National Park Service vessels, or on foot (Caine's Head). Personnel from the Kenai Fjords National Park have indicated they will provide space on their vessels for this purpose.

If Pigeon Guillemot nests at these colonies are accessible, we will band nestlings. Resightings of these guillemots at ASLC will provide information on dispersal distance for this species. Intercolony visits are common for pre-breeding alcids (Harris 1983, Kress and Nettleship 1989), and in 1999 we will search these colonies for banded individuals that were raised in captivity at ASLC in 1998.

Objective 2. Validation and Calibration of Nondestructive Biomarkers for Monitoring the Health and Exposure to Oil of Guillemots

a. Measurement of Certain Blood Biomarkers of Petroleum Hydrocarbon Exposure

In the second year of this study (CY 99), research on blood biomarkers of oil exposure will include controlled dose-response experiments with weathered Prudhoe Bay crude oil (PBCO). A range finding experiment will be conducted to determine the no-effect dose for guillemot chicks consuming weathered PBCO. We will also determine the time course of biomarker response to ingestion of PBCO, including the time post-ingestion when biomarker induction is no longer detectable. At 20, 25, and 30 days post-hatch, we will feed guillemot chicks small, sublethal doses of weathered PBCO in number 2 gelcaps that are inserted into the abdominal cavity of a fish that is then fed to the nestling. Five to six guillemot nestlings from each of the four diet treatments (see below) will be assigned to each of the following oil ingestion treatments: control, 0.25 ml of weathered PBCO, 0.5 ml of weathered PBCO, and 1.0 ml of weathered PBCO. Control chicks will receive 1 ml of corn oil in a number 2 gelcap inserted in a food fish. We know from previous experiments (Prichard et al. 1997) that a dose of 0.2 ml of weathered PBCO ingested three times during the latter part of the nestling development period does not have a significant effect on growth of Pigeon Guillemots. Consequently, these doses are designed to identify the "no-effect" dose for weathered PBCO.

Just before and following ingestion of the oil dose, we will collect 1 ml of blood in heparinized vials by puncturing the brachial vein. Blood samples will be collected at 0 h, 12 h, 24 h, and 48 h post-injestion of oil. Previous experiments (Prichard 1997) indicate that there is no significant difference in blood biomarker levels five days after oil dosing, so this time course of blood samples is designed to reveal the time course of biomarker induction from crude oil injestion. Blood samples will be kept cool and centrifuged at 3,000 rpm for 20 minutes. Plasma will then be removed with a pipette and stored in snap-top plastic vials at -20oC for laboratory analysis at the University of Alaska Fairbanks. In the lab, we will measure haptoglobin and other acute phase protein levels in plasma samples in order to determine dose-response and time course of the response. Assays for blood biomarkers will be conducted in the laboratory of Dr. Larry Duffy at the University of Alaska Fairbanks. Dose-response will be compared among the four diet groups (see below) to assess the role of diet in determining biomarker induction in blood in response to PBCO ingestion.

b. Measurement of Biomarkers in Excreta

In addition to collection of blood samples, samples of excreta will be collected over 24-h intervals each day after the intitial dosing of PBCOin order to measure fecal porphyrin levels and determine dose-response and time course of response. As with blood biomarkers, responses in fecal porphyrin levels will be compared among the four diet groups. Measurements of fecal porphyrins in excreta will be conducted in the laboratory of Dr. Larry Duffy at the University of Alaska Fairbanks.

Objective 3. Captive Feeding Trials to Assess the Relationship between Diet and Postnatal Development in Guillemots

a. Comparison of Guillemot Growth Performance on Diets of Nearshore Demersal Fish vs. High-lipid or Low-lipid Schooling Forage Fish

In CY 99, 20-25 guillemot chicks will be raised on each of four diets: (1) 160 g of crescent gunnels per day, (2) 160 g of herring per day, (3) 160 g of sand lance per day, 160 g of juvenile pollock per day. All of these prey species are major components of guillemot chick diets at certain sites and the four species are representative of the two primary prey types in guillemot diets: nearshore demersal fishes and schooling forage fishes. These daily rations are designed so as to provide a variety of caloric and lipid consumption rates that are within the normal range experienced by guillemot nestlings, but biomass consumption rates would be the same for each diet group. Herring and sand lance are representative of high-lipid forage fishes with relatively high energy densities. Juvenile walleye pollock are representative of low-lipid forage fishes with relatively low energy densities. Crescent gunnels are typical on nearshore demersal fishes with intermediate lipid content and energy density. Each chick will be kept in a separate cage so that food consumption can be monitored individually. The daily rations will be provided to most chicks in four daily feedings of 40 g each at about 10:00, 13:00, 16:00, and 19:00 ADT. Each day prior to the first feeding the body mass, wing length, and outer primary length of each chick will be measured until each captive-reared chick fledges into the wild, at about 35-40 days post-hatch. Return rates of subadults in the third and fourth year of this study will allow us to assess the role of prefledging nutrition and fledging mass on subsequent post-fledging survival.

CY 2000

In 2000 all of the direct restoration activities listed above for 1999 will be conducted. Additionally, after 1999 we will attempt to locate guillemots that were raised at the Alaska SeaLife Center at regional colonies during our surveys.

Also in 2000, we will conduct additional dose-response experiments with captive-reared guillemot chicks that build on the results of 1999 experiments to validate the use of certain biomarkers for assessing the health status and oil exposure of wild guillemot chicks. These experiments will emphasize acute phase proteins, such as haptoglobin and hemaplexin, which are known to be induced in birds in response to disease, trauma, or other stress. Finally, we will investigate the role of weathering in reducing the toxicity of PBCO by comparing results of dose-response experiments using PBCO that has been weathered for different periods. Small sample sizes of dosed and undosed (control) chicks will be sacrificed for measurement of CP-450 levels in liver tissues and to examine nasal gland tissues for hypertrophy.

Captive feeding trials in 2000 will continue to investigate the relative quality of various prey types commonly fed to guillemot chicks by their parents. Additional experiments will be designed to explore the tradeoffs for guillemot nestlings of meal size, meal frequency, and meal quality. This will be accomplished by raising guillemot chicks on isocaloric rations (same number of calories ingested per day) of large or high energy density prey fed infrequently vs. small or low energy density prey fed frequently. The growth rates and fledging condition of

chicks raised on these various diets will be compared, and subsequent survival post-fledging will be assessed from return rates of captive-reared adults to the natal site. Small samples of chicks raised on the different diet regimes will be sacrificed to measure body composition using proximate analysis techniques. The results of these captive feeding trials will enable us to interpret guillemot diet data that are collected as part of long-term monitoring activities and assess the availability and quality of forage fishes for breeding guillemots.

Approval of the field protocols for work with live birds described in this DPD have been obtained from the Institutional Animal Care and Use Committee at Oregon State University and are pending from ASLC. Any take of eggs or incidental/unintentional take of nestling or adult guillemots will be covered by relevant Federal and State Scientific Collecting permits. All fledgling, captive-reared guillemots released to the wild will be banded with USFWS stainless steel leg bands and polyvinyl colored leg bands under a Master Station banding permit held by the Oregon Cooperative Fish and Wildlife Research Unit.

C. Contracts and Other Agency Assistance

Laboratory analyses of the biochemical composition and energy content of forage fishes fed to captive guillemots and the proximate composition of chick carcasses will be conducted in the laboratory of the PI at Oregon State University.

Analyses of biomarkers in blood plasma and fecal samples will be conducted in the lab of Dr. Lawrence K. Duffy at the University of Alaska Fairbanks, where the expertise is available to perform this task.

SCHEDULE

A. Measurable Project Tasks for CY 99 (February 1, 1999 - January 31, 2000

March 1 - May 15:	Install artificial nest sites, decoys, and playback sound equipment at SeaLife Center.
May 15 - August 31:	Collect field data on guillemot use of artificial nest sites, raise guillemot nestlings in captivity, conduct captive rearing experiments, and release captive-reared fledglings.
Sept. 1 - Dec. 31:	Enter, analyze, and interpret field data and data collected from captive-reared chicks. Conduct laboratory analyses of plasma samples, diet samples, and chick carcass samples.
January 1 - 14:	Prepare for Annual Restoration Workshop
January 15 - 24:	Attend Annual Restoration Workshop and present FY 99 results to peer reviewers.
Jan. 24 - April 14:	Prepare 1999 annual report of findings.
April 15:	Submit annual report (FY 99 findings) Submit FY 00 DPD to Trustee Council
March 16 - April 30:	Arrange logistics and prepare for FY 00 field season and captive-rearing experiments.

B. Project Milestones and Endpoints

CY 99

May 15, 1999	Installation of artificial nest sites, decoys, and audio equipment near the Alaska SeaLife Center
August 31, 1999	Completion of second field season, release of second cohort of captive-reared nestlings, collection of blood and fecal biomarker samples for dose-response experiment, completion of captive-feeding trials comparing nestling growth performance on schooling forage fish and nearshore demersal fish.
April 30, 1999	Completion of second annual report of findings
CY 00	
August 31, 2000	Completion of second year of a two-year experimental study of the role of diet on nestling growth performance and dose-response experiments with ingested crude oil Completion of field work and Objective 1
CY 01	
June 30, 2001:	Completion of M.S. thesis
September 30, 2001	Completion of Objectives 2 and 3 and submission of manuscripts addressing these objectives

C. Completion Date

The anticipated completion of this project will be early in FY 02, at the end of calendar year 2001. This will allow adequate time to complete data analysis, thesis preparation by the Masters student, and manuscript preparation and submission following the last field season in 2000 and completion of laboratory analysis early in 2001.

PUBLICATIONS AND PROJECT REPORTS

The following publications are projected for this research project (this is a rough projection and by no means complete):

An annual report for the second year of this project will be submitted by 15 April 2000. The final report for this project will be submitted 15 December 2001. At least three manuscripts will be generated from this research, and all will be published in the peer-reviewed scientific literature. Each of these three manuscripts will address one of the three major objectives/hypotheses of this study: (1) guillemot colony establishment as a direct restoration technique, (2) biomarkers as a means of assessing exposure of guillemots to crude oil, and (3) diet as a factor in nestling growth and post-fledging survival. A portion of the final report will be excerpted from the thesis of the M.S. student on this project. This student will be strongly encouraged and directly assisted by the PI to submit for publication in the peer-reviewed scientific literature the results from this research.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The research described in this proposal takes advantage of the new research facilities and potential represented by the Alaska SeaLife Center and dove-tails nicely with continuing research as part of the APEX and NVP projects that assesses factors limiting recovery of Pigeon Guillemot populations damaged by EVOS. It is also relevant to efforts toward developing seabird models as upper trophic level sentinels of oil pollution in nearshore ecosystems. The proposed research approach utilizes growth performance, fledgling body condition, and blood

and fecal biomarkers to assess the health status of guillemot nestling exposed to oil and raised on different diet rations. These data are essential for developing techniques for long term monitoring of the health and status of guillemot populations in the EVOS area.

Studies of foraging, reproduction, and population recovery following the EVOS are on-going for pigeon guillemots. This proposal complements and enhances other studies on pigeon guillemots, without duplication of effort. The PI on the present proposal has been and will continue to work closely with David Irons and Greg Golet (PIs on APEX Component 99163 F "Factors Affecting Recovery of PWS Pigeon Guillemot Populations"), Dave McGuire (Co-PI on NVP studies of biomarkers of oil exposure in guillemot nestlings), and John Piatt (PI on APEX Components 99163 M "Lower Cook Inlet Forage Fish Studies" and 99163 N "Black-legged Kittiwake Feeding Experiment") in developing protocols for collecting data.

PRINCIPAL INVESTIGATOR

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The PI has extensive experience with studies of the reproductive biology of high latitude seabirds and the relationship between diet composition and productivity. He is currently the PI of the Seabird Energetics component (Component G) of the APEX Project and Co-PI of the Diet Quality and Chick Growth component (Component N) of the APEX Project. He has been involved in research on the factors constraining recovery of Pigeon Guillemots in the EVOS area for the last three years.

OTHER KEY PERSONNEL

The proposed research will be implemented by the Oregon Cooperative Fish and Wildlife Research Unit, closely coordinated with and in cooperation with personnel of the Alaska SeaLife Center in Seward. The PI will receive major assistance in conducting the direct restoration aspects of this research project from George Divoky, Postdoctoral Research Associate, who has over 20 years of research experience with guillemots and has been instrumental in designing techniques for direct restoration of guillemot populations. In addition, the PI will be assisted in experiments with captive-reared chicks by Andrew Hovey, a graduate student in the Department of Fisheries and Wildlife at Oregon State University, and an undergraduate research assistant. Laboratory analyses of the proximate composition of diet samples and chick carcasses will be conducted in the laboratory of the PI at Oregon State University. Assays of plasma and fecal biomarkers will be conducted in the laboratory of Dr. Lawrence Duffy at the University of Alaska Fairbanks. To the PI's knowledge, the expertise and equipment necessary for the proposed research are not available within the federal and state agencies that comprise the Trustees Council.

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EVOS Trustee Council	Pigeon Guillemot Restoration at the SeaLife Center - YEAR 2				
USGS-BRD Budget		FY 99		FY 99	
		On-Campus	Subtotals	Off-Campus	Subtotals
SALARY					
	Graduate Student Stipend, Ph.D. (9 mo @ $1,575/mo)	$14,175			
	Graduate Student Salary - Field season (3 mo @ $1,850/mo)			$5,550	
	Research Assistant - Field, 12 wk. @ $1,600/mo			$4,800	
	Subtotal Salary		$14,175		$10,350
BENEFITS					
	Graduate Student, Ph.D. 1%OPE, 9 mos.	$142			
	Graduate Student, summer hire, 5% OPE, 3 mos.			$278	
	Research Assistant, Field, 10.0% OPE, 12 weeks			$480	
	Subtotal Benefits		$142		$758
TRAVEL					
	Travel to SeaLife Center for research, 4 rt @ $630/ea			$2,520	
	Transportation in Alaska for field personnel to collect eggs (Air fare, air charter, boat charter)			$10,000	
	Per Diem en route to egg collection sites @ $120 ea			$2,400	
	Travel to Anchorage for Restoration Workshop, PI meetings - 2 RT- $420/rt	$840			
	Per Diem in Anchorage for meetings, 6 days @ $120/day	$720			
	Subtotal Travel		$1,560		$14,920
SERVICES					
	Personal Services Contract to Dr. George Divoky			$27,500	
	Housing in Seward for 3 (4 mo @ $78.75/day)			$9,450	
	Lab/Office space at SeaLife Center *			TO BE DETERMINED	
	Duplication/computer fees	$1,000			
	Lab analyses of blood & excreta samples for biomarkers (L. Duffy, UAF) (acute phase proteins in blood, fecal porphyrins)			$7,500	
	Shipping for samples	$700			
	Publication - reports, visual aids	$921			
	Vehicle rental from Anchorage airport to Seward			$1,000	
	Maintenance for field equipment			$1,200	
	Telephone services - long distance charges	$1,500			
	Subtotal Services		$4,121		$46,650
EQUIPMENT					
	Subtotal Equipment		$0		$0
COMMODITIES					
	Cages for raising chicks			$500	
	Nest boxes/sites			$2,000	
	Decoys, playbacks, other social attractants			$2,000	
	Binoculars, spotting scopes, tripods, for observing guillemots at SeaLife			$2,500	
	Egg collecting equipment			$500	
	Incubators			$300	
	Blood sample collection supplies			$2,000	
	Food for personnel at Seward, 3 people, 15 weeks @ $210/week)			$3,150	
	Ohaus top-loading balance, battery-powered			$600	
	Food for chicks			$2,000	
	Bands and banding supplies			$400	
	Miscellaneous supplies for captive rearing			$1,500	
	Subtotal Commodities		$0		$17,450
STUDENT ASSISTANCE					
	Tuition for Ph.D. student (3 academic terms/year)	$5,639	$5,639		
TOTAL DIRECT COSTS		$25,637	$25,637	$90,128	$90,128
Modified Total Direct Costs (less tuition, equipment)		$19,998	$19,998	$90,128	$90,128
INDIRECT COSTS		$8,499	$8,499	$23,433	$23,433
	42.5% MTDC (On-Campus Research Rate)				
	26% MTDC (Off-Campus Research Rate)				
TOTAL COSTS (direct and indirect)		$34,136	$34,136	$113,561	$113,561
TOTAL COST OF PROJECT (Off-campus and On-campus)		$147,697			

* estimated cost for lab or office space (per John Hendricks) is $870/mo, or $6,090 for use of office space (4 mo) and lab space (3 mo). Trustee Council to negotiate rate and potentially reimburse SeaLife Center directly.

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99328

Synthesis of the Toxicological and Epidemiological Impacts of the *Exxon Valdez* Oil Spill on Pacific Herring

Project Number:	99328
Restoration Category:	Synthesis, Integration, and Publication
Proposer:	Mark G. Carls NMFS, Auke Bay Laboratory ABL Program Manager: Dr. Stan Rice NOAA Program Manager: Bruce Wright
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska Sea Life Center:	No
Duration:	One year
Cost, FY99:	$79,300
Cost, FY00:	$0
Geographic Area:	Prince William Sound (field work completed)
Injured Resource/Service:	Pacific herring

ABSTRACT

This project would synthesize results of toxicological and epidemiological damage to Pacific herring (but not the ecological research still in progress), and compare Trustee-sponsored conclusions to those of Exxon investigators. Trustee researchers concluded that exposure to oil caused egg mortality, morphological and cytogenetic abnormalities, reduced growth, and immunosuppression in adults, but that effects on the population level were unknown. Exxon investigators concluded that the spill had a minor impact on herring eggs, and that the population did not decrease. Also discussed are hypotheses concerning the cause of the 1993 population collapse in PWS, including disease and possible linkage to the oil spill. A monograph for publication would be prepared, and presented at the 10th anniversary symposium.

INTRODUCTION

Two very different interpretations of results emerged from the *Exxon Valdez* oil spill impact studies, divided along industry and Natural Resource Damage Assessment (NRDA) lines. These divided conclusions form a common theme among various species (including herring, salmon, and birds), ecosystems (such as recovery of intertidal biota), and sediment chemistry. Exxon investigators consistently concluded that oil effects were smaller in magnitude, spatial, and temporal extent than did NRDA investigators. We propose to explore this dichotomy for just one species, Pacific herring.

Did the *Exxon Valdez* oil spill impact herring in 1989 and 1990? Pearson et al. (1995a,b) concluded effects of the *Exxon Valdez* oil spill on Pacific herring in Prince William Sound (PWS) were generally negligible. Pearson et al. (1995a,b) argue that 1) very few spawned herring eggs were exposed to *Exxon Valdez* oil (4%), 2) effects on eggs were minor in 1989, even in oiled areas, 3) spill effects were not evident in 1990, and 4) herring population levels did not decrease. The NRDA studies draw very different conclusions: 1) the oil trajectory overlapped 41-52% of the total herring egg population in PWS (Brown et al. 1996a), 2) effects on eggs and larvae were significant in 1989 (McGurk and Brown 1996a; Hose et al. 1996; Norcross et al. 1996; Marty et al. 1997), 3) eggs may have been impacted by residual oil as late as 1992 (Kocan et al. 1996a,b), 4) population effects were unknown (EVOSTC). Also at issue is the toxicity of *Exxon Valdez* oil: Pearson et al. (1995a,b), based on previous water-soluble fraction (WSF) literature, argue that aromatic concentrations in PWS were generally far below toxic levels, but current NRDA studies indicate that PAH composition is an important factor in determining toxicity, and conclude that concentrations in PWS were in the toxic range (Carls et al. submitted [a]; Heintz et al. submitted).

What caused the collapse of the herring fishery in 1993 in Prince William Sound? Elston et al. (1997) argue that poor nutritional condition, coupled with cold winter temperatures, and possibly a cyclical density-dependent downturn in population numbers could have caused the collapse of the herring population. In contrast, Brown et al. (1994) suggested a linkage between the previous oil spill and the population collapse, and hypothesized that recruitment of an immunologically damaged 1989 year class may have been responsible for the collapse.

Were herring affected by oil in 1989? Were they affected by oil in 1993? These questions illustrate the need for a synthesis study that examines the Trustee and industry evidence.

Many research projects have been completed or are nearing completion concerning impacts of the *Exxon Valdez* oil spill on Pacific herring in Prince William Sound. These projects fall into three broad topic areas: toxicological, epidemiological, and ecological. Investigative progress in each of these areas has varied. Toxicological questions were addressed beginning immediately after the spill, and most of this research has been completed and published. Disease research was stimulated by the 1993 herring population collapse, and is nearing completion. Ecological research concerning herring, which has been associated with several Trustee-sponsored programs, is the least complete at present. For this reason, and because of the potentially very broad context of a single synthesis effort, we recommend that synthesis efforts be split into at least two main topics: toxicological and epidemiological (FY99), and ecological or

oceanographic (FY00). Principal investigators for these two separate syntheses will not be the same. The current synthesis proposal is limited to toxicology and disease, and limited to a one year effort.

NEED FOR THE PROJECT

A. Statement of Problem

Conflicting interpretations of the extent of injury emerged from Natural Resource Assessment Studies and those by Exxon investigators. Exxon investigators concluded that the spill had a minor impact on herring eggs, and that the population biomass was not reduced (Pearson et al. 1996). State and Federal researchers concluded that exposure to oil caused egg mortality, morphological and cytogenetic abnormalities, reduced growth, and immunosuppression in adults (Brown et a. 1996; Carls et al. submitted [b]; Hose et al. 1996; Kocan et al. 1996ab; Marty et al. 1997; McGurk and Brown 1996; Norcross et al. 1996; Thomas et al. 1997), but that the effects on the population level were unknown (EVOSTC 1996). However, herring were placed on the injured species list. Of particular concern was the population collapse in 1993, viewed as a possible delayed consequence of prior spill damage. The proposed synthesis will review published papers and reports pertinent to Pacific herring and the *Exxon Valdez* oil spill, and will integrate Trustee-sponsored toxicological and epidemiological research. The synthesis will also discuss Exxon investigator findings, and attempt to resolve differences.

B. Rationale/Link to Restoration

This project relates directly to the Oil Spill Restoration Plan objective to recover healthy and productive Pacific herring populations to pre-spill abundance. The significance and causes of long term damage will be evaluated; restoration and management strategies need this information.

C. Location

Prince William Sound is the geographic focus, but this synthesis project does not require additional field or laboratory work.

COMMUNITY INVOLVEMENT

Because all field work has been completed, opportunity for community involvement is very limited.

PROJECT DESIGN

A. Objectives

1. Synthesize results of Trustee-sponsored toxicological and epidemiological studies relating to long-term injury and recovery of Pacific herring. All major hypotheses from contributing studies would be examined in the synthesis manuscript.

2. Evaluate and incorporate into the synthesis all of the relevant Exxon-funded research, and attempt to reconcile differences with Trustee-sponsored research where possible.

B. Methods.

A minimum of 20 toxicological and epidemiological papers related to Pacific herring and the *Exxon Valdez* oil spill will be reviewed as the primary focus of the synthesis. Other peripheral papers and the Trustee hydrocarbon database will be utilized as needed. Writing will begin October 1, 1998, and continue into March 1999. The synthesis will be ready for presentation at the 10th anniversary symposium, and for submission to a peer-reviewed journal by June 1999. There will be one author meeting to review the scope of the paper, refine the outline, and determine writing assignments. Most other author interaction will take place by email or phone. Research considered in this effort would include NRDA and Restoration research funded by the *Exxon Valdez* Oil Spill Trustee Council and research published by *Exxon* investigators.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

Coauthors will include Dr. Gary Marty (University of California, Davis), Dr. Jo Ellen Hose (Occidental University), and Dr. Richard Kocan (University of Washington). Dr. Stan Rice (Auke Bay Lab) will have management oversight, and will serve as a major reviewer and quality control.

SCHEDULE

A. Measurable Project Tasks for FY98 (October 1, 1998 - September 30, 1999)

We propose to start this project in FY99. Some subjects for the review are in hand now, others will be completed in FY99. Egg and larval work relating to genetics and morphology have been completed, but some disease research and papers have not yet been completed (e.g., Marty et al.; Kocan et al.).

Oct 98:	Begin writing synthesis paper
Nov 98:	Author meeting; discuss subject matter and organization, and assign writing.
Jan 99:	Toxicological section complete for review by other authors
Feb 99:	Disease section complete for review by other authors
Mar 99:	Complete oral presentation of synthesis; present at symposium
May 99:	Complete internal review
Jun 99:	Complete manuscript; submit to peer-reviewed journal
Sept 99:	Respond to reviewers; return edited manuscript for publication.

Target journal: Canadian Journal of Fisheries & Aquatic Sciences

B. Project Milestones and Endpoints

Jan 99:	First section of manuscript complete
Mar 99:	First draft complete and available for review
	Present synthesis at symposium
Sept99:	Synthesis in press.

C. Completion Date

This project would be completed in Fiscal Year 1999.

PUBLICATIONS AND REPORTS

This project would produce a publication that would synthesize results of the separate Trustee-sponsored studies on toxicological and epidemiological impacts of the *Exxon Valdez* oil spill on Pacific herring, and compare these results to those published by Exxon investigators. It would begin in FY99, and be submitted for publication in a peer-reviewed journal in September 1999.

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

PROFESSIONAL CONFERENCES

The synthesis product could be presented at the 1999 SETAC conference.

NORMAL AGENCY MANAGEMENT

NOAA/NMFS has statutory stewardship for most 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 will be coordinated with other projects conducted by ABL and ADF&G.
This project is dependent on the completion of the Trustee projects relevant to toxicological and epidemiological impacts on Pacific herring.

PROPOSED PRINCIPAL INVESTIGATOR

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PRINCIPAL INVESTIGATOR

Mark G. Carls (GS-12 Fishery Biologist)

Received BA (1975) in Biology from Gustavus Adolphus College, St. Peter, MN, and MS (1978) in Biological Oceanography from Dalhousie University, Halifax, Nova Scotia. Mark has been employed at the Auke Bay Fisheries Laboratory since 1979. His principal involvement has been in research of petroleum hydrocarbon toxicology to marine fish and invertebrates, including egg, larval, and adult life stages. Mark has published 17 papers, and has 5 *Exxon Valdez* damage assessment papers in preparation or pending publication. Since 1989, he has been involved as a principal investigator and co-investigator on several studies resulting from the *Exxon Valdez* oil spill involving Pacific herring, pink, and chum salmon.

OTHER KEY PERSONNEL

Cooperating investigators will include Dr. Gary Marty (University of California, Davis), Dr. Jo Ellen Hose (Occidental University), and Dr. Richard Kocan (University of Washington). Dr. Stan Rice, Jeff Short, Marie Larsen, Dr. Adam Moles, Ron Heintz, and other colleagues at ABL will assist in reviews and quality control of the synthesis. Bonita Nelson will assist in Trustee database searches.

LITERATURE CITED

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1996 EXXON VALDEZ T[illegible]TEE COUNCIL PROJECT BUDGET

October 1, 1995 - September 30, 1996

Budget Category:	Authorized FFY 1998	Proposed FFY 1999	LONG RANGE FUNDING REQUIREMENTS					
			Estimated FFY 2000	Estimated FFY 2001	Estimated FFY 2002	Estimated FFY 2003	Estimated FFY 2004	Estimated FFY 2005
Personnel	$0.0	$39.0						
Travel	$0.0	$6.0						
Contractual	$0.0	$26.6						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0						
Subtotal	$0.0	$71.6						
General Administration	$0.0	$7.7						
Project Total	$0.0	$79.3	$0.0					
	$0.0							
Full-time Equivalents (FTE)	$0.0	0.4						
	Dollar amounts are shown in thousands of dollars.							
Other Resources		$19.6	$0.0					

Comments:

Personnel cost assumes salary coverage of 1 man-month per contributing author (contractual), plus 3 additional man-months for the coordinator (salary), and 1 month salary for program oversight.

Other Resources:

NOAA contribution is estimated: Principal Investigator M. Carls, 2 mo. @ 14.1K, Habitat Program Manager Dr. S. Rice .5 mo @ 5.6K for a total NOAA contribution of 19.6K.

1999

Prepared:

Project Number: 99328
Project Title: HERRING SYNTHESIS MANUSCRIPT
Agency: National Oceanic & Atmospheric Administration

FORM 3A
AGENCY
PROJECT
DETAIL

1996 EXXON VALDEZ T[illegible]TEE COUNCIL PROJECT BUDGET

October 1, 1995 - September 30, 1996

Personnel Costs:			GS/Range/	Months	Monthly		Proposed
PM	Name	Position Description	Step	Budgeted	Costs	Overtime	FFY 1999
	Mark Carls	Fishery Biologist	12/5	4.0	7,000		28.0
	Dr. Stan Rice	Program Manager	14	1.0	11,000		11.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		5.0	18,000	0	
Those costs associated with program management should be indicated by placement of an *.						**Personnel Total**	$39.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
PM	Description	Price	Trips	Days	Per Diem	FFY 1999
	Anchorage, Symposium, 3 trips, 3 days/person	410	3	9	150	2.6
	Car Rental/Miscellaneous for above					1.0
	ticket price reflects average price					
	total days assumes 3 day workshop for 8 people					
	per diem is based on federal rate					
	Sacramento, Planning meeting, 5 trips, 1 day/person	250	5	4	150	1.9
	Car Rental/Miscellaneous for above					0.5
						0.0
Those costs associated with program management should be indicated by placement of an *.					**Travel Total**	$6.0

1999

Project Number: 99___
Project Title: HERRING SYNTHESIS MANUSCRIPT
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Personnel
& Travel
DETAIL

1996 EXXON VALDEZ T[illegible]TEE COUNCIL PROJECT BUDGET
October 1, 1995 - September 30, 1996

Contractual Costs:			Proposed
Description			FFY 1999
	man-months	rate	
Dr. Gary Marty	1	9600	9.6
Dr. Jo Ellen Hose	1	10000	10.0
Dr. Dick Kocan	1	7000	7.0
When a non-trustee organization is used, the form 4A is required.		**Contractual Total**	$26.6
Commodities Costs:			Proposed
Description			FFY 1999
		Commodities Total	$0.0

1999

Project Number: 99___
Project Title: HERRING SYNTHESIS MANUSCRIPT
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Contractual & Commodities DETAIL

1996 EXXON VALDEZ T[illegible]STEE COUNCIL PROJECT BUDGET
October 1, 1995 - September 30, 1996

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FFY 1999
			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
Computers & printers	2	NOAA
Slide scanner	1	NOAA
Camera	1	NOAA
Photo output device	1	NOAA

1999

Project Number: 99___
Project Title: HERRING SYNTHESIS MANUSCRIPT
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Equipment
DETAIL

Synthesis of the Toxicological Impacts on Pink Salmon

Project Number:	99329
Restoration Category:	Synthesis, Integration, and Publication
Proposer:	Stanley D. Rice NMFS, Auke Bay Laboratory ABL Program Manager: Dr. Stan Rice NOAA Program Manager: Bruce Wright
Lead Trustee Agency:	NOAA
Cooperating Agencies:	ADFG
Alaska SeaLife Center:	No
Duration:	2nd year, 1.5-year project
Cost FY 99:	$52,500
Cost FY 2000:	$0
Geographic Area:	Prince William Sound (field work completed)
Injured Resource/Service:	Pink salmon

ABSTRACT

This proposal requests funds to close out Project 329 (Synthesis of the Toxicological Impacts on Pink Salmon). Project 329 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 after 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). Project 329 will synthesize results of these studies and provide 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 will be prepared which 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* oilspill. At the 1997 Restoration Workshop, keynote speaker Dr. Kai Lee emphasized the need for syntheses such as Project 329 to bring cohesiveness to the Trustee's multi-faceted research program.

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 a synthesis all of the relevant EXXON-funded results, and reconcile differences where possible.

B. Methods

Data from all Trustee-sponsored studies have been collected. Project 329 will produce a synthesis that will 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 have agreed 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 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 99

This project started in FY 98 because delaying the start to FY 99 would not allow enough time to provide a product and presentation in FY 99. The focus in the first half of FY98 is to complete various component parts of manuscripts from other projects. The sythesis will start in the second half of FY98 and continue into FY99. Some subjects for the review are in hand now; others will be completed in FY 99. Results from the oiled stream sediment project (Project 194) are available and are currently being evaluated. The data evaluation phase of the straying project (Project 076) is nearing completion and will be available by mid FY 98 to be incorporated into this synthesis project.

Completed:

October-December 1997:	Collated data from final reports from all Trustee-sponsored studies and all appropriate EXXON studies related to toxicological impacts on pink salmon. Made presentations at SETAC meetings by Rice, Heintz, Short, (and Exxon). Met with principal investigators, including Brian Bue and Mark Willette of ADFG, to evaluate the status of past studies, reports, and manuscripts. Reviewed the Brannon/Maki EXXON review; developed some partial critiques.

To be completed in FY 98:

April - September 1998:	Meet with principal investigators; formulate outline and schedule for the monograph; develop component parts to the synthesis. Focus in last half of FY 98 would be the final report from the straying project, (the last significant unfinished component part), and the development of specific themes. Present material during a joint Trustee/EXXON panel at AFS meeting in Sept. 1998 in Anchorage.

To be completed in FY 99:

October- December 1998:	First draft of monograph completed; co-author reviews.
January - March 1999:	Complete the Murphy stream sediment paper and final report, submit by March (important component of synthesis). Complete second draft of Manuscript. Prepare for symposium presentation.
March 1999:	Present synthesis at the 10th Anniversary Symposium.
April 1999:	Submit synthesis monograph to journal for publication.

B. Project Milestones and Endpoints

January 1998:	Data from final reports collected and tabulated.
June 1998:	Outline of monograph prepared.
December 1998:	Draft monograph synthesis completed and available for co-author review.
March 1999:	Synthesis presented at the 10th Anniversary *Exxon Valdez* Oil Spill Symposium.
April 1999:	Monograph synthesis completed and submitted for publication.

C. Completion Date

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

PUBLICATIONS AND REPORTS

Project 329 will produce a monograph publication that will synthesize results of the separate Trustee-sponsored studies on toxicological impacts on pink salmon. It began in FY 98, and if this proposal is funded, it would be finished in FY 99. The synthesis monograph would be submitted for publication in a peer-reviewed journal in April 1999.

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

NORMAL AGENCY MANAGEMENT

NOAA/NMFS has statutory stewardship for most 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

Stanley D. Rice
NOAA NMFS Auke Bay Laboratory
11305 Glacier Hwy
Juneau, AK 99801
Phone: (907) 789-6020; Fax: (907) 789-6094
E-mail: jeep.rice@noaa.gov

Cooperating Investigators (Co-authors)

ABL	ADFG
Alex Wertheimer	Jim Seeb
Mike Murphy	Brian Bue
Jeff Short	
Ron Heintz	

PRINCIPAL INVESTIGATOR

GM-14 Physiologist - Stanley D. Rice

Dr. Stanley D. Rice received a BA (1966) and MA (1968) in Biology at Chico State University, and Ph.D. (1971) in Comparative Physiology at Kent State University. Employed at the Auke Bay Laboratory since 1971 as a research physiologist and task leader, Dr. Rice has been Habitat Program Manager since 1986. He has researched oil effects since 1971 and has published over 80 papers on the subject, and over 20 papers on other pollution/physiological subjects. Dr. Rice was the lead editor for the *Exxon Valdez* Symposium published in 1997. His studies have ranged from field to lab tests, behavioral to biochemical studies, and salmonids to invertebrates. Dr. Rice has conducted and managed cooperative projects since 1974, including the Auke Bay Laboratory's *Exxon Valdez* damage assessment studies. Activities since the oil spill include management of more than 10 damage assessment projects, more than 25 restoration projects, establishment of chemistry lab and analyses, and establishment of hydrocarbon database management. Dr. Rice has provided reviews and critical input to principal investigators and managers in NOAA and other agencies to support agency decisions, and he has interacted closely with other agencies on logistics coordination, study design review, and data interpretation. Over 100 publications.

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999	PROPOSED FY 1999 TRUSTEE AGENCIES TOTALS					
			ADEC	ADF&G	ADNR	USFS	DOI	NOAA
				$10.9				$35.5
Personnel	$19.5	$40.4						
Travel	$1.9	$3.8						
Contractual	$0.0	$0.0						
Commodities	$1.2	$2.2						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$22.6	$46.4		Estimated FY 2000	Estimated FY 2001	Estimated FY 2002	Estimated FY 2003	
General Administration	$3.0	$6.1						
Project Total	$25.6	$52.5		$0.0	$0.0	$0.0	$0.0	
Full-time Equivalents (FTE)	0.2	0.4						
Other Resources	$0.0	$30.6		$9.0	$0.0	$0.0	$0.0	$21.6

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Lead Agency: NOAA

FORM 2A
MULTI-TRUSTEE
AGENCY
SUMMARY

Prepared:4/10/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999	LONG RANGE FUNDING REQUIREMENTS					
				Estimated FY 2000	Estimated FY 2001	Estimated FY 2002	Estimated FY 2003	
Personnel	$19.5	$31.4						
Travel	$1.9	$1.9						
Contractual	$0.0	$0.0						
Commodities	$1.2	$2.2						
Equipment	$0.0	$0.0						
Subtotal	$22.6	$35.5						
General Administration	$3.0	$4.7						
Project Total	$25.6	$40.2						
Full-time Equivalents (FTE)	0.2	0.3						
Other Resources	$0.0	$21.6						

Comments:

NOAA Contributions
Habitat Program Manager, Dr. Stan Rice, 1 mo = $11.3K, Fishery Biologist, M. Murphy 1 mo. = $7.0K, Fishery Biologist R. Heintz .5 mo. @3.3 for a total NOAA contribution of: 21.6K

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Prepared:4/10/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Personnel Costs:		GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FY 1999
Name	Position Description					
Stanley Rice	Physiologist	14	1.0	9.6		9.6
Jeffrey Short	Research Chemist	13	0.5	8.4		4.2
Alex Wertheimer	Fisheries Research Biologist	13	0.5	8.0		4.0
Ron Heintz	Fisheries Research Biologist	12	1.0	6.6		6.6
Mike Murphy	Fisheries Research Biologist	12	1.0	7.0		7.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		4.0	39.6	0.0	
					Personnel Total	$31.4

Travel Costs:	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FY 1999
Description					
Travel to EVOS Anniversary Symposium, Anchorage-Juneau	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

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

Prepared:4/10/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed FY 1999
Description	
computer repairs, maintenance, and software upgrades	1.2
preparation of reports, reprint costs	1.0
Commodities Total	$2.2

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3B
Contractual & Commodities DETAIL

Prepared:4/10/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
			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

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: NOAA

FORM 3B
Equipment
DETAIL

Prepared:4/10/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel	$9.0	$9.0
Travel	$1.9	$1.9
Contractual	$0.0	$0.0
Commodities	$0.0	$0.0
Equipment	$0.0	$0.0
Subtotal	$10.9	$10.9
General Administration	$1.4	$1.4
Project Total	$12.3	$12.3
Full-time Equivalents (FTE)	0.1	0.1
Other Resources		$9.0

LONG RANGE FUNDING REQUIREMENTS

	Estimated FY 1999	Estimated FY 2000	Estimated FY 2001	Estimated FY 2002	

Dollar amounts are shown in thousands of dollars.

Comments:

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

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Prepared:4/10/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 1999
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 1999
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

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3B
Personnel
& Travel
DETAIL

Prepared:4/10/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed FY 1999
Description	
Commodities Total	$0.0

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3B
Contractual & Commodities DETAIL

Prepared:4/10/98

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
			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

1999

Project Number: 99329
Project Title: Synthesis of Toxicological Impacts on Pink Salmon
Agency: ADFG

FORM 3B
Equipment
DETAIL

Prepared:4/10/98

PROJECT TITLE: MASS-BALANCE MODELS OF TROPHIC FLUXES IN EVOS-IMPACTED AREAS: OPTION PERIOD I -- TROPHIC FLUXES ALONG THE KENAI SHELF AND OUTER COOK INLET.

Project Number:	99 330
Restoration Category:	Ecosystem Synthesis
Proposer:	Daniel Pauly, Fisheries Centre, University of British Columbia, Vancouver, and Stuart Pimm, Ecology and Evolutionary Biology, University of Tennessee, Knoxville
Primary Contact:	Thomas A. Okey, UBC Fisheries Centre, tokey@fisheries.com
Lead Trustee Agency:	NOAA
Cooperating Agencies:	
Alaska Sea Life Center:	no
Duration:	2nd year, 2-year project
Cost FY 99:	$173,474
Cost FY 00:	$ 000,000
Geographic Area:	Prince William Sound, the Kenai shelf, and outer Cook Inlet
Injured Resource/Service:	All injured biological resources and all damaged services

ABSTRACT

Support is requested for the second year of a two-year project to construct, validate, and disseminate whole food-web models of Prince William Sound (PWS) and adjacent marine areas affected by the Exxon Valdez Oil Spill (EVOS). These mass-balance models of flows among trophic levels and among ecosystem components are ideally suited to synthesize the extensive information gathered by various research groups after the 1989 *Exxon Valdez* spill. This is especially true in light of the collaborative process nurtured during year one of this project and because of new landmark developments in the ECOPATH software. Synthesis of this, and other, information through our tailored ECOPATH process will lead to optimization of ecosystem level insights into the impacts of EVOS and other anthropogenic stressors. The second year of this project will consist of three main components: 1) the production of a CD-ROM for the public domain, incorporating an interactive graphic version of the PWS trophic model developed during year 1 as well as user-friendly databases on the biology and local/traditional knowledge of the marine organisms of PWS and beyond (to be ready for initial presentation and distribution at the 10th Annual Restoration workshop in March of 1999); 2) the option of a 2-day workshop in late January of 1999 devoted to constructing an Ecopath model of the Kenai shelf and outer Cook Inlet, attended by researchers from the Gulf of Alaska region, 3) extended study and shelf model development by project staff.

INTRODUCTION

Our ongoing project, *Mass Balance Model of Trophic Fluxes in Prince William Sound* (Project # 98330), is primarily designed to help fulfill the often-stated need of integrating and synthesizing what is being learned from the various research and monitoring projects within Exxon Valdez Oil Spill (EVOS) restoration programs, 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). This current proposal is focused on year 2 of our two-year project (Option Period I). It can be titled *Mass-Balance Models of Trophic Fluxes in Impacted Areas: Option Period I--Trophic Fluxes Along the Kenai Shelf and Outer Cook Inlet.*

Our proposal of April 10, 1997, which was approved, outlined a program in which we would construct trophic models, based on the well-documented and used ECOPATH software (Christensen and Pauly 1992a, b, 1995, Pauly and Christensen 1993, Pauly and Christensen 1995, and other authors in Christensen and Pauly 1996). One model would cover the period prior to the oil spill and be based largely on published or pre-existing information. The structure of a second post-spill model would be based on inputs by researchers who are authorities on the ecosystem components of Prince William Sound (PWS) and adjacent areas, most of which have received EVOS funding and have yet-unpublished data. In particular, this latter model would incorporate information from APEX, SEA, and NVP programs--three large EVOS programs which incorporate efforts to model particular segments of the PWS ecosystem.

By working with these various experts, we would seek a broad and inclusive ecosystem synthesis of the larger Prince William Sound and adjacent segments of the Gulf of Alaska (affected shelf areas) and the complex changes within them. We envisioned that this broad participation, and the collaborative process used for model specification, would ensure that the product would be perceived as a useful compliment to existing EVOS research. We went on to suggest that this different level of analysis would provide ecosystem-level insights into both the structure and function of these systems and the effects of EVOS and other perturbations on the systems in question.

The pre-spill model of Prince William Sound is completed and available from the Fisheries Centre (Dalsgaard and Pauly 1997), and it is posted on our project web page at <http://fisheries.com/project.pwsound.htm>. A well-attended initial working lunch was held in conjunction with the 1998 EVOS restoration workshop at which principal investigators and other researchers attended. Construction of the post-spill ECOPATH model was initiated during a 3-day workshop held in Anchorage on March 2-4, at which representatives from the three major EVOS ecosystem programs were present and contributed. Construction of this collaborative post-spill model of Prince William Sound is well underway, as is the development of the corresponding report (see the above project web page for more information on this workshop and the overall project). As a corollary to these efforts, an e-mail network has been established among the PWS ECOPATH model contributors[1].

[1] Note: it is our perception, as well as the communicated perception of participants and others, that there now exists a higher degree of enthusiasm and acceptance of the ECOPATH approach for this setting than generally expected based on previous skepticism and reluctance within the overall EVOS community. We also believe that this exercise has spawned increased interaction and discussion among research groups.

The second year of this project will consist of 3 main components:

1) Production of a CD-ROM for the public domain, incorporating an interactive graphic version of the PWS trophic model developed during year 1 as well as the inclusion of user-friendly databases on the biology and local/traditional knowledge of the marine ecosystem and organisms of PWS and beyond (to be ready for initial presentation and distribution at the 10th Annual Restoration workshop in March of 1999);
2) The option of a 2-day workshop in late January of 1999 devoted to constructing an Ecopath model of the Kenai shelf and outer Cook Inlet, attended by researchers from the Gulf of Alaska region (the alternative to this workshop is individual meetings between the project coordinator and identified contributors where necessary);
3) Development of shelf model through extended study and coordination with experts.

To ensure the acceptability and wide dissemination of the model among the public as well as among managers, the CD-ROM product will be made available for distribution through the Trustee Council and appropriate trustee agencies to interested organizations and institutions, including schools. This CD-ROM 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

The EVOS Trustee Council stated the need for our project quite precisely on page 53 of its invitation for 1997 proposals: "... many data sets [generated by EVOS projects] on the distribution, abundance and productivity of many species and ecological communities ... 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". This goal (request) is now emphasized more strongly than ever in the invitation for 1999 proposals (Page 31).

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, their predators, or both. A great deal of information has been collected about these segments of the ecosystem, and in some cases the resolution of this information is high. The goal of the ECOPATH model is to use measures of central tendency and their ranges to explore the relationships among the best estimates of biomass, productivity, consumption, and diet composition to reveal patterns of energy flow among the components. The precision of these estimates varies among ecosystem components, but since all components of the defined ecosystem are included and balanced (while accounting for imports and exports) the approach enables learning, modification, and verification of distinct components as well as insights into whole ecosystem structure and function. The precision of estimates for a particular group incorporates the resolution of information collected for that group. Within the ECOPATH framework then, the precision gained from the large investments in some programs enables increased knowledge of less-understood components. In addition to

gaining a better understanding of individual resource components and their potential trajectories in an ecosystem context, as well as ecosystem structure and function, trophic flow models can provide the tools and information for studies of contaminant fate and transport, though this study does not focus on the latter application.

The ECOPATH models being developed during this project will provide useful and explicit insights into most of the injured resources and all of the services listed in Table 4 on page 42 of the invitation for 1999 proposals. The following two boxes contain questions that can be addressed by the ECOPATH approach.

Initial Questions - Our initial-year proposal listed the following possible specific questions that could be addressed using the ECOPATH approach.

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 effect does this have on 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?

Additional Questions - These "what if" scenarios were contributed by EVOS and NMFS program scientists (B. Spies, B. Wright, A. Gunther) during the PWS model specification workshop to be used as possible perturbations to the model PWS model.

1. What if fishing pressure on herring increases or decreases; what if there is one stock of herring? two? three?
2. What if somebody decides to fish sandlance or capelin? this is probably far-fetched, but model simulations would likely show important trophic impacts of removing important forage fishes.
3. What if an earthquake raises the upper 10m of intertidal above sea level?
4. What if PWSAC goes broke and the hatcheries close?
5. What if there is another oil spill?
6. What if human impacts from the road to Whittier result in damage to intertidal habitats in the western part of PWS?
7. What if recreational fishing pressure removes 90% of the rockfish from PWS?
8. What if there is a major warm-water episode for 2 years with the upper 200 m of water over the shelf in the GOA is elevated by 2 degrees C ?
9. What if the bloom and sustained productivity lasts only for 3 weeks instead of the usual 12 weeks in PWS ?
10. What if the harbor seals continue to decline at 8% per year ?
11. What if dungeness crab return to PWS?
12. What if salmon prices drop or increase?
13. What if pollock disappear from PWS?
14. What if salmon farming were allowed in PWS?
15. What if a road were established to Cordova?
16. What if cruise ship traffic increases into Cordova?

B. Rationale/Link to Restoration

A quantitative description of the whole trophic structure of PWS and adjacent waters and the relationships between the different species and groups that inhabit the area will place the results of individual EVOS projects into a realistic context and enable marine resource policy planning on an ecosystem level (multi-species as opposed to single species). Such a description and management approach does not exist. For example, an ECOPATH model of PWS will enable analysis of shifts in the trophic structure in the wake of the oil spill that might be hindering the recovery of seabirds and marine mammals. Likewise, a quantitative analysis of the relationships between seabird foraging and hatchery-released fish will help to identify problems in the restocking program. Another subject potentially resolvable through ECOPATH is the complex interactive relationship between the impacts of fishing and the

impacts of the oil spill. Numerous other examples exist. 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 interest to those involved in policy making and restoration.

Rationale for mass-balance trophic models

Biological production (expressed as energy or carbon) in a given ecosystem must be either exported or consumed locally. Furthermore, the biological production of a given group that is not exported must be equal to the amount of that group consumed 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 reveal thermodynamically "possible" trophic models of ecosystems. Models of this sort can then be used to make 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).

To gain realistic insights into the ecosystem-level effects of a perturbation like a catastrophic oil spill, some understanding of interactions among ecosystem components is necessary. Indeed, counter-intuitive indirect effects may appear several trophic linkages away from their cause (Abrams 1992, also see Vanni 1987a, 1987b). In the Bering Sea, for example, a locally concentrated pollock fishery may have 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). The ECOPATH approach provides a quantitative framework for tracking such indirect, ecosystem-level, effects.

But beyond these tremendously useful static representations of ecosystems, the data in ECOPATH files can be directly used in simulation models of the system (ECOSIM). A quasi-static sequence of ECOPATH models can provide insights into ecosystem changes, but many questions require investigation of the dynamic behavior of the system. Dynamic ECOSIM models allow rapid exploration of the predicted consequences of various intervention or events (e.g. restocking, selective harvesting, or changes in some physical forcing functions). Once the PWS ECOPATH model is constructed, balanced, and ready, perturbations can be tailored to resemble real anthropogenic disturbances, such as the EVOS oil spill. Management actions and strategies can likewise be simulated.

In addition to the present integral features of ECOSIM, we will specifically tailor a dynamic model for each of the two major areas of interest. The additional modeling effort will resolve deeper issues often vital to the understanding and wise management of the system. These include questions of the resistance and persistence of the system, system stability under a wide range of situations, vulnerability of individual species and even whole subwebs, the sensitivity and characteristic response modes to changes, and estimates of recovery times. We aim to derive direct indicators potentially saving thousands of model runs in Monte Carlo simulations.

ECOSIM simulation models

To study indirect effects, or ecosystem-level effects, of a perturbation, the system of linear equations underlying mass-balance models can be re-expressed as a system of coupled differential equations using a new module (ECOSIM) of the ECOPATH software (Walters et al., 1997). 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. "...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.)

This is done by linearizing the dynamic models and applying the powerful methods of linear systems analysis to answer basic questions about stability and response. Monte Carlo

experiments will be important for investigating "what if" questions, but doing so with the *a priori* knowledge of the basic system characteristics will sharpen the process and make it far more efficient.

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. In this way, the work of project staff is tailored to requirements identified during the specification workshops and through interaction with contributors.

A great deal can be learned from ECOSIM simulation models to aid resource managers in making decisions that affect the development of these communities. Perhaps even more importantly, the outputs and implications of ECOSIM model runs are easily graspable to anyone because of the friendly user interface and graphics that are clear and intuitive. Indeed, we believe that the accuracy, precision and ease of use of the PWS model will be more than adequate to reveal and predict functional and structural responses to virtual manipulations

The newest development to the ECOPATH approach is a spatially explicit component of ECOSIM called ECOSPACE. The ECOSPACE approach may well revolutionize the modeling of ecosystems. It is clear that organisms, or components, in an ecosystem are distributed spatially, and thus organize and concentrate their interactions within and according to particular spatial distributions. With this reality in mind, ecosystem models that do not incorporate spatially explicit analysis seem woefully inadequate. Already, contributors of the PWS post-spill model were asked during the workshop held in Anchorage to provide information on the spatial distribution of their components according to a diagrammatic representation of PWS that was then incorporated into the graphical ECOSPACE routines. This new approach was demonstrated at the PWS workshop on March 2-4 by enabling the different ecosystem components to "interact' and thus re-distribute themselves in space, within the context of trophic flow.

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 in which coverage of Alaskan fishes will be enriched by incorporation of biological and local/traditional knowledge of all marine biotic resources of the study regions.

C. Location

The area covered by Prince William Sound was defined during our PWS workshop held in Anchorage on 2-4 March, and it was graciously represented by the Alaska Biological Science Centre, USGS, using a GIS package with which J. L. Bodkin and colleagues also provided areal estimates for different depth zones for PWS (see this color map at the project web site at <http://fisheries.com/project.pwsound.htm>). This area closely corresponds to the area used in the PWS pre-spill model (report found at project web site). The area to be included in the second post-spill model includes the marine areas adjacent to PWS, the Kenai

Peninsula, and the outer Cook Inlet, but final definition of area will be made by consensus among contributors. 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

The ultimate goal of community involvement and input into the models constructed for PWS and adjacent areas is that the experience of fishers and hunters will be considered when specifying the models. The proximate task for achieving this ultimate goal will begin by developing a database based on the local names of fishes and other marine organisms within the study area. All accessible names in all appropriate native languages will be the basis for this database. The next step will be to focus on traditional knowledge of life history and interactions for each of the organisms. This database will be incorporated into the report as a separate section, but more importantly it will be incorporated into the Alaska-region FishBase and other databases on the CD-ROM. We hope that this will provide access of this information to the whole spectrum of communities and age groups that might be interested and inclined to contribute. All local/traditional knowledge on the fishes and other organisms of the PWS region to be included in FishBase will rely on published sources, as the project does not include a field component. 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

Previously stated objectives for this project were:

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;
7. Enter biological information, local names in local languages, and local knowledge (so far 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 workshop to present and disseminate the final product (in 10), and teach its use;
12. Present the project and its products at every opportunity, especially at conferences and in the primary literature.

These objectives were either accomplished, or are underway and will be completed during FY 99. In the case of objectives 2-5, however, development and integration of separate models was not necessary. Ecosystem components were defined and partitioned and then individuals from each of the groups mentioned contributed information about the components to which they were assigned. Two additional components proposed for FY 99 are:

13. Use essentially the same method to construct an Ecopath model of the Kenai Shelf and the Outer Cook Inlet;
14. Enable the models to be run in a spatially-explicit manner using Ecospace by expressing spatial distributions of all organisms.

B Methods

Please refer to our initial project proposal of 10 April 1997 for an outline and discussion of the specific methodologies of developing an Ecopath model. The following paragraphs focus on the basic methods of accomplishing the three project components specified in the introduction section of the current proposal.

Component 1 - The CD-ROM product proposed for production (proposed here and in our accepted initial proposal) will serve as a receptacle and a vehicle for much of the work in this project. Project products to be made accessible through this CD-ROM include the working PWS Ecopath model including Ecosim and Ecospace features and databases of Alaskan fishes and other marine organisms with accessibility through native languages. The completion of this CD-ROM in time for the 10th annual EVOS workshop will be accomplished through the following tasks:

- Construction, analysis, and presentation of the PWS Ecopath model during year 1;
- Development of the database of local names and traditional knowledge of organisms;
- Development of a database on Alaska Fishes within FishBase, through contract;
- Incorporating and enabling use of databases that include other taxa (eg. Whiskers);
- Development of user-friendly packaging of included components, through contract;
- Physical production of the CD-ROM product, through contract;
- Arrangement for dissemination at the 10th annual EVOS meeting, and elsewhere.

Component 2 - The goal of this component is to develop an Ecopath model of some of the areas outside of PWS affected by the EVOS. Based on our experience constructing Ecopath models, we consider that this component will proceed most efficiently if our team maintains options for two scenarios for collecting information for development of this additional model. The first scenario is to hold a 2-day workshop in late January of 1999 similar to the successful workshop held for the PWS model specification. The second scenario is for

project staff to coordinate with experts and researchers for these areas using the same type of collaborative approach where each expert would contribute to the model through an edited report and participants would be part of a list-server group. Meetings between the project coordinator and individual experts would be arranged opportunistically or where necessary. Justification for the second scenario includes: 1) our existent contact with some of the researchers who we would invite to be contributors for this additional model; 2) many of these researchers will already be familiar with the ECOPATH approach; and 3) individual meetings may be more convenient for these researchers than a workshop in January of 1999. We have not decided on either scenario at this point; we consider that it will be far more appropriate to make this decision in November of 1998 rather than now. Either scenario will lead to the same outcome, and we predict that the budget would be the same for either of these scenarios.

Component 3 - A considerable amount of work is involved in producing the content of the deliverables for this project. This work consists mainly of (1) constructing and balancing the models, 2) analysis of the ecosystems using the models (including simulations which follow the questions outlined in Section A above); (3) editing and producing the multi-authored model reports; and (4) coordinating with contributing experts and others. Thus, extended work and study is needed by project staff to accomplish these goals. Most of this work can be done at the respective universities of the involved staff, but some travel and field interaction may be necessary, especially given the second scenario of component 2 above.

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 have been contacted and invited to participate, along with other experts, in the PWS model specification workshop, and the subsequent validation process. This process is ongoing, and we consider the initial stages to have been successful.

In year two, the Fisheries Centre, UBC, will subcontract item 7 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 10 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: Literature search on names in the local language and traditional knowledge of marine organisms in PWS and adjacent areas covered

by the Shelf model. Identification and coordination with experts on ecosystem components of the Shelf model area.

2) Jan. 28-29: Two-day workshop on construction of the Shelf model

3) March 10: Completion of the CD-ROM containing the PWS Ecopath model and packaged, graphical simulation scenarios; an Alaska Fish database including local and traditional names; other databases covering other components of the ecosystem

3) March 23-26: Attend 10th anniversary EVOS restoration workshop and present project results and progress focusing on presentation of the CD-ROM product containing some of the project results.

B. Project Milestones and Endpoints

FY 99 Milestones (besides required annual reports):

Nov. 1998:	Incorporation of explicit seasonally into PWS ECOPATH Model and submission of scientific paper on subject.
Jan. 1999:	Holding of PWS Model Specification Workshop;
March 1999:	Presentation of results at EVOS 10th anniversary conference;
May. 1999:	Publication of Shelf model report;
Jun. 1999:	Submission of scientific papers documenting key features and behavior of trophic mass-balance models including ECOSPACE paper;
September 1999:	Final dissemination of project results and products

C. Completion Dates

As for "Milestones;" project will be completed in September of 1999 (FY 99)

PUBLICATIONS AND REPORTS

The above project milestones identify anticipated publications, reports, and other deliverables. The publication record of the Principal Investigators are invoked here: we will document and publish our work in the primary literature.

PROFESSIONAL CONFERENCES

The principal investigators 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. The project work to date will be presented at the 16th Lowell Wakefield Fisheries Symposium in Anchorage Alaska on September 30 to October 3, 1998, just before a one day project presentation workshop on October 5.

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")

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

Three main differences exist between the current DPD and the DPD approved by the Trustee Council for FY 98: (1) We are proposing to construct a model of areas outside of PWS affected by EVOS including the Kenai shelf and the outer Cook Inlet. The focus of the project has somewhat shifted from the before-after comparison to coverage of larger affected areas. This shift in focus enables additional analysis and is justified because uncertainties in the pre-spill model will likely remain relatively high. (2) Models and analysis will include a spatially-explicit component through the use of the ECOSPACE part of the ECOSIM analyses. (3) Two different methodological scenarios are included as options for accomplishing the construction of the aforementioned shelf model. This option is necessary because the end of this calendar year is a more appropriate decision point for the shelf model strategy.

PROPOSED PRINCIPAL INVESTIGATORS

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PRINCIPAL INVESTIGATORS

Dr. Daniel Pauly - The key qualifications of Dr. Pauly are having initiated, while still at ICLARM, Manila, Philippines, the activities which led to the emergence of the ECOPATH approach and software, and of FishBase, and to have authored a large number of primary literature publications documenting these. Further, he has organized several workshops (including one in the Pacific Northwest) and training courses at which the ECOPATH approach was taught and used.

Dr. Stuart L. Pimm is on the editorial boards of Conservation Biology, Evolutionary Ecology, Journal of Animal Ecology, Oecologia, and Science. He has also participated on several major committees such as the National Research Council Committee on Preservation of the 'Alala; the Scientific Advisory Board, the Centre for Conservation Biology, Stanford University; the American Institute of Biological Sciences Task force for the 90s, and the National Research Council Committee on the Value of Biodiversity. He has also given Testimony to the Federal Senate Committee on the Environment; the re-authorization of the Endangered Species Act; July 13th 1995, and the House Committee on Resources; the re-authorization of the Endangered Species Act; September 20th 1995. He is the author of numerous scientific papers in distinguished journals and a book, among others, on food webs.

OTHER KEY PERSONNEL

Dr Carl Walters, Professor, Fisheries Centre, UBC, who developed the ECOSIM module of ECOPATH;

Dr Tony Pitcher, Director, Fisheries Centre UBC, who will serve as Project Manager, and a staff member to be hired by the project;

Robert D. Powell, Senior Research Associate, Department of Ecology and Evolutionary Biology, The University of Tennessee, who will develop models at the University of Tennessee;

Thomas A. Okey, M.S., Project Coordinator / Marine Ecologist, Fisheries Centre, UBC, who will continue development of the current, tailored collaborative process, coordinate the shelf Ecopath workshop in Year 2, and edit the PWS and shelf model reports.

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FY 99 EXXON VALDEZ TRU[illegible] COUNCIL PROJECT BUDGET
October 1, 199[illegible] eptember 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel	$92,550.0	$103,980.0
Travel	$30,880.0	$22,660.0
Contractual	$2,800.0	$14,500.0
Commodities	$3,710.0	$3,050.0
Equipment	$9,680.0	$400.0
Subtotal	$139,620.0	$144,590.0
Indirect	$28,380.0	$28,883.6
Project Total	$168,000.0	$173,473.6
Full-time Equivalents (FTE)	29.5	21.2
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

Estimated FY 2000	Estimated FY 2001	Estimated FY 2002
$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 services, administration, space and buildings, computer facilities, basic office supplies and communications. They are calculated at the standrad UBC contract rates for ' non-commercial government and NGOs' of 30% of the cost of personnel and 2% or travel costs. Note: rates for S. Pimm and B. Powell are calculated at the UTC rate of 23%.

FY 99

Prepared: 04/07/1998

Project Number: 330
Project Title: A Mass Balance Model of the Trophic Fluxes along the Kenai shelf and the outer Cook Inlet
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4A
Non-Trustee
SUMMARY

FY 99 EXXON VALDEZ TRU[illegible]E COUNCIL PROJECT BUDGET
October 1, 199[illegible] September 30, 1999

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FY 1999
Dr Daniel Pauly	PI - UBC Fisheries Centre		1.0	9000.0		9,000.0
Dr Stuart Pimm	PI - U. Tenn.		1.5	9000.0		13,500.0
Dr Carl Walters	numerical modeller - UBC Fisheries Centre		0.2	9000.0		1,800.0
Dr Tony Pitcher	ecologist, project manager, UBC -FC		0.5	9000.0		4,500.0
Robert D. Powell	research associate - U. Tenn.		6.0	4330.0		25,980.0
Thomas A. Okey, MS	project coordinator- UBC Fisheries Centre		12.0	4100.0		49,200.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		21.2	44430.0	0.0	
					Personnel Total	$103,980.0

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 1999
UBC PI, modeller + proj. coordinator to 10th EVOS mtg+shelf model v	700.0	4	21	130.0	5,530.0
PI Pimm and Powell to 10th annual EVOS meeting+shelf model work	1000.0	4	16	130.0	6,080.0
PI Pimm and Powell to Vancouver to help coordinate modeling	850.0	2	10	130.0	3,000.0
					0.0
Shelf Model Development					0.0
Scenario 1:					0.0
3 US participants to shelf model workshop - non-Alaskans	900.0	3	9	130.0	3,870.0
7 US participants to shelf model workshop - Alaskans	300.0	7	16	130.0	4,180.0
Scenario 2:					0.0
Individual meetings with contributors as necessary by project staff (the same budget would apply)					0.0
					0.0
				Travel Total	$22,660.0

FY 99

Project Number: 330
Project Title: A Mass Balance Model of the Trophic Fluxes along the Kenai shelf and the outer Cook Inlet
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4B
Personnel
& Travel
DETAIL

Prepared: 04/07/1998

FY 99 EXXON VALDEZ TRU[illegible]E COUNCIL PROJECT BUDGET
October 1, 19[illegible]September 30, 1999

Contractual Costs:	Proposed
Description	FY 1999
Report draft, editing, binding and delivery	2,500.0
Production of multi-cultural Alaska Ecopath / Fishbase CD-Rom	
Entry of Alaska Ecopath and fish information into Fishbase database	6,000.0
Database design and supervision by senior scientist	1,000.0
Database arrangement and physical production of CD-Rom	5,000.0
Contractual Total	$14,500.0

Commodities Costs:	Proposed
Description	FY 1999
computer supplies	1,100.0
offic and secretarial	400.0
LAN charges	900.0
Fax, phone, postage	650.0
Commodities Total	$3,050.0

FY 99

Prepared: 04/07/1998

Project Number: 330
Project Title: A Mass Balance Model of the Trophic Fluxes along the Kenai shelf and the outer Cook Inlet
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4B
Contractual & Commodities DETAIL

FY 99 EXXON VALDEZ TRU[illegible]E COUNCIL PROJECT BUDGET
October 1, 199[illegible] September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
hard drive upgrade for laptop at UTK	1	400.0	400.0
			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**	$400.0

Existing Equipment Usage: Description	Number of Units

FY 99

Project Number: 330
Project Title: A Mass Balance Model of the Trophic Fluxes along the Kenai shelf and the outer Cook Inlet
Name: Fisheries Centre UBC, U of Tennessee, Knoxville

FORM 4B
Equipment
DETAIL

Prepared: 04/07/1998

Project Title: **Sea Otter Monoriting**

Project Number: 99333

Restoration Catagory: General Restoration

Proposer: Native Village of Eyak

Lead Trustee Agency:

Cooperating Agencies:

Duration:	Five Year
Cost for FY 99:	$250,000
Cost for FY 00	$250,000
Cost for FY 01	$250,000
Cost for FY 02	$250,000
Cost for FY 03	$250,000

Geographic Area: Oil Spill Effected Area

Injured Resource/Service: Subsistence

ABSTRACT

Orca Bay in front of Eyak/Cordova, is the home to one of the largest Sea Otter herds in the world.

Over the past twenty years, the local processors practice of grinding up fish waste and pumping out into the bay has provided an additional food source for sea otters. The amount of fish waste reachs 50 million pounds in some years. Sea otters have eaten everything else that there is to eat and this fish waste is a main staple of their diet.

Recent autopsies have shown that the bones in this fish waste has poked holes in sea otter's intestines and they have picked up parasites from this fish waste.

These parasites could spread to other marine mammals and other fish. This could possible cause major problems with sea life throughout Alaska.

99335

Proposal For Building and Operating a Sockeye Hatchery In Nanwalek, Alaska

Nanwalek Sockeye Project

Justification

Benefits

The most significant benefits of a sockeye hatchery in Nanwalek are as follows:

- Local Year Round Employment

Village residents would gain access to potential year round employment opportunities which would help stimulate the village economy and serve to increase local awareness and participation in this important resource enhancement program.

- Easier Logistics for NSP Operations

The project would be easier to manage and operate efficiently by having all aspects of the project locally operated.

- Complete Village Ownership of the Sockeye Enhancement Project

By having the entire project located in Nanwalek, the village and its residents would have more direct control of and participation with the project and its outcomes. This would result in a more direct sense of ownership and pride in the project for the village. By being more completely involved in the project and it's outcomes, more local people would be likely to get involved in the project and would have a higher level of awareness and interest in project activities.

Steps Needed to Build the Sockeye Hatchery in Nanwalek

- Form a Hatchery Board
  - Incorporate
    - File Articles of Incorporation
    - Need at Least Three Original Incorporators
      - This will be the Initial Hatchery Board
  - Create and Adopt Bylaws
  - Solicit General Membership
  - Annual Meeting, Elect Officers and any new Board Seats

- Apply For and Obtain Necessary Permits
  - Apply for Private Non Profit (PNP) Permit
    - Get Packet from Juneau
    - Fill Out and Return
    - Modify as Needed
  - Acquire any other Necessary Permits

- Establish Hatchery Location
  - Come Up With Short List of Three Sites
  - Create Review Criteria
    - Water (Quantity, Quality and Delivery)
    - Logistics (How Far, Response Time in Emergencies etc,)
    - Land Aquisition (Cost, Convenience etc.)

Rate all Sites Fairly and Decide on Location Based on Score

- Line up Funding
  - Apply For Grant Funds
    - Submit application for and pursue grant funds for capital expenditures and first two years of operations.
  - Design and Implement Cost Recovery Program to Self Sustain Project
    - Work towards an efficient program which with reasonable success, would allow for sufficient funds to be generated by taking enough cost recovery fish each year to pay for project while leaving the majority of the fish for the subsistence and commercial users.

- Hire Staff
  - Need Responsible and Dependable Hatchery Personnel
    - Two Full Time Positions
      - Hatchery Manager and Assistant Manager or Senior Fish Culturist
      - Establish Pay Rate, Fair, its very hard work, yet affordable
  - Be Supportive, Expect a Lot and Acknowledge Their Hard Work

- Start Construction
  - Draft and Finalize Hatchery Plans
  - Bid Out Materials List
  - Use Local People
  - Use Separate Water Delivery Crew
    - Install Water Intake Structures
    - Dig Trenches
    - Run Piping
    - Plumb up The Incubators and Headboxes.

Specific Needs

Incubators

- Need 12 NOPAD Incubators
- Or 6 Kitoi Box Incubators
- NOPADs Are Preferable, Less Risk
- Flow Requirements
  - NOPAD's = 24 gpm
  - KITOI's = 40 gpm

Space Requirements

- Need 20' by 20', Two Story Building
- Must Have Road or Good Trail Access

Building Needs

- Must Have at Least an 8' Ceiling
- Needs Washable Water Proof Floors and Walls, with Drains
- Reliable Heat Source
  - Keep from Freezing and to Keep Crew from Freezing
- Double Door Access

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

Project Number:	99338
Restoration Category:	Research
Proposed By:	U.S. Geological Survey (PI- John F. Piatt)
Lead Trustee Agency:	DOI-BRD
Cooperating Agencies:	DOI-FWS
Duration:	2nd year, 3-year project
Cost FY 99:	$57,900
Cost FY 00:	$45,000 (data analysis, reporting)
Cost FY 01	$0
Cost FY 02	$0
Geographic Area:	Cook Inlet, Gulf of Alaska
Injured Resource:	Multiple resources

ABSTRACT

Some seabird populations damaged by the *Exxon Valdez* oil spill continue to decline or are not recovering. In order to understand the ultimate cause of seabird population fluctuations, we must measure productivity, recruitment, and adult survival. Current APEX studies are focused on measuring productivity only. Recruitment measurement demands an unrealistic study duration. We propose to 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 most limiting to 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 1995-97 (APEX, project no. 99163) 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 99163M). Results of past 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 continued 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. 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. Foraging stress from breeding effort is probably a major contributor to adult overwinter mortality (Golet et al. 1998). Our work will enhance 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. 99163M) measures 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. 99163M), 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

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.

3. To relate differences in common murre and black-legged kittiwake overwinter survival to differences in breeding success.

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 99163M (APEX) and 99306 (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 phase. All-day watches give information on nest-site attendance, foraging trip duration, and chick provisioning rate. 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

Resighting efforts to search for birds banded during FY98 work will commence in late May and early June 1999. 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. Resighted birds' position in the colony will be noted on archival plot photos or sketches.

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.

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 or equivalent will 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

Measurable Project Tasks for FY 99

Oct. 1-Jan. 31:	Evaluate results of FY98 work; refine study design
Feb. 1-April 15:	Arrange logistics (resighting, capture and banding, nest monitoring, etc.)
March 23-27:	Attend 10th Anniversary Symposium
April 15:	Submit Annual Report (FY98 findings)
April 16-Sept. 10:	Conduct field work
Sept. 11-Sept. 30:	Compile resighting results; begin data analysis

Project Milestones and Endpoints

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

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.

PRINCIPAL INVESTIGATOR

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PRINCIPAL INVESTIGATOR

Dr. John F. Piatt, Research Biologist (GS-13) with the Alaska Science Center, Biological Resources Division, USGS in Anchorage. Obtained a Ph.D. in Marine Biology from Memorial University of Newfoundland in 1987 (dissertation on seabird-forage fish interactions). Since 1987, studied seabirds at colonies and at sea in Gulf of Alaska, Aleutians, Bering and Chukchi seas. Author on 45 peer-reviewed scientific publications about seabirds, fish, marine mammals, and effects of oil pollution on marine birds. Responsible for coordination and oversight of the proposed research.

PROJECT LEADER

Thomas I. Van Pelt, MSc. student. Over five years of experience working in Gulf of Alaska and Aleutian marine ecosystems. Responsible for project design, logistics, data analysis, and preparation of manuscripts and reports.

OTHER KEY PERSONNEL

Ann Harding, April Nielsen, Mike Shultz, and Steph Zador (USGS/BRD staff involved with APEX project) will share responsibility for banding, resighting, and data management.

COLLABORATORS

Dr. David B. Irons, Migratory Bird Management, USFWS. Extensive experience with seabird survival studies in Prince William Sound. Will collaborate on project design, and provide technical guidance.

Dr. Alexander S. Kitaysky, University of Washington, Dept. of Zoology. Will collaborate on study design and field work.

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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

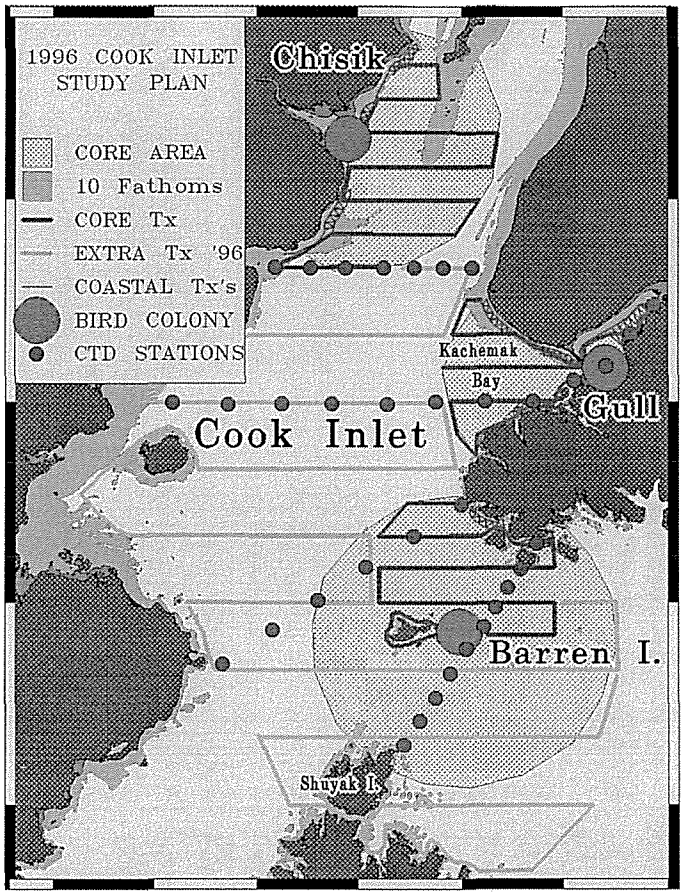
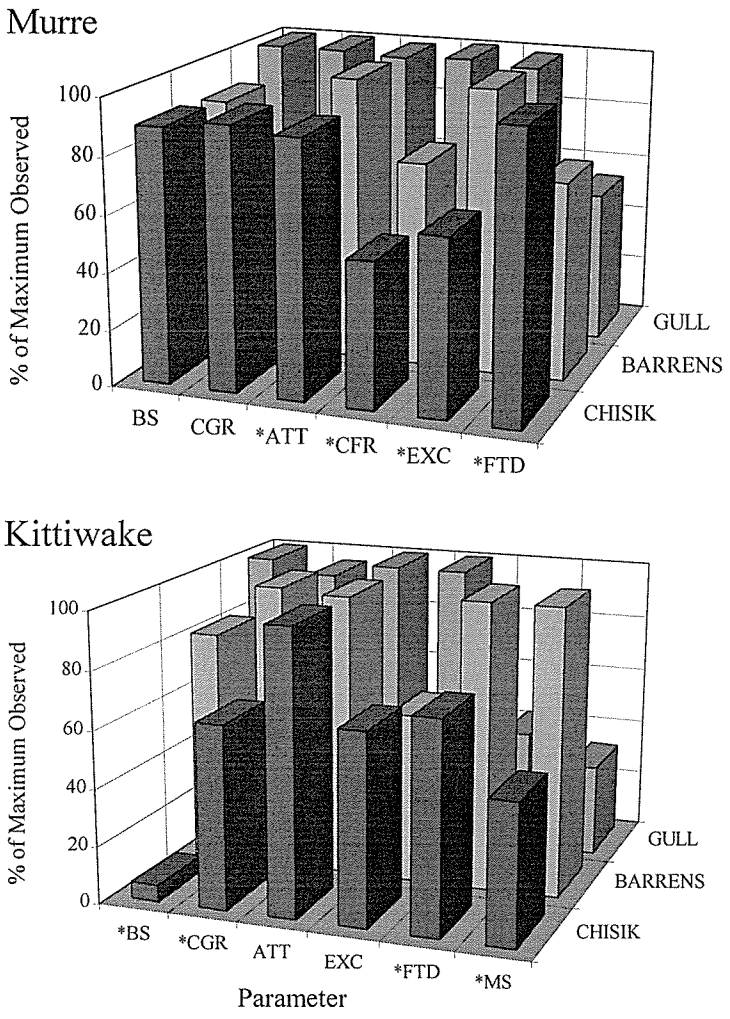


Figure 1. Study area in lower Cook Inlet. Colonies proposed for study of adult survival are located on Chisik and Gull Islands.



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.

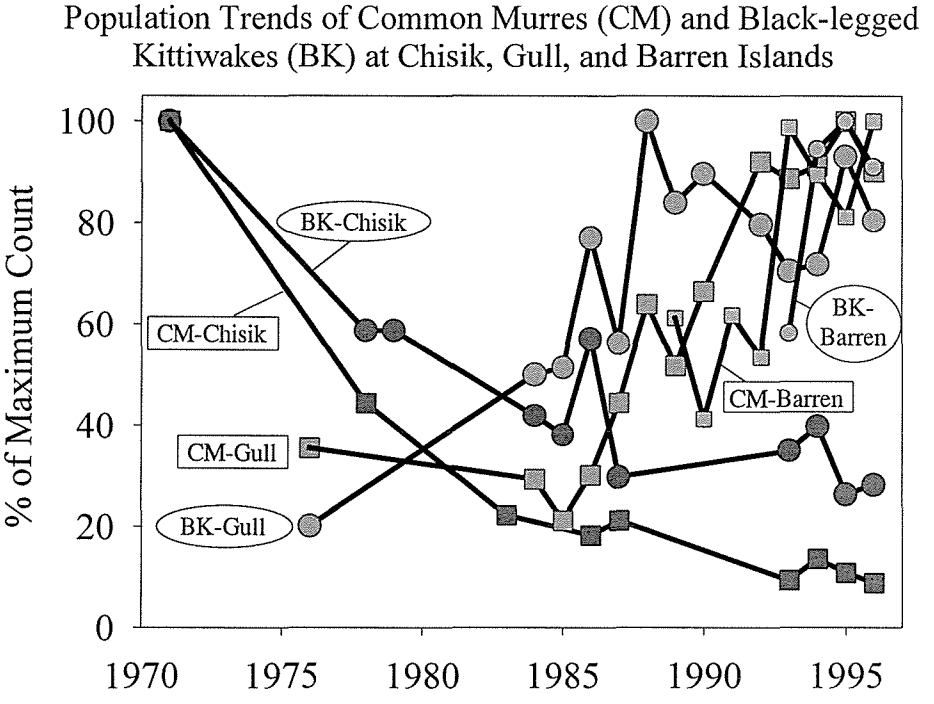


Figure 3. Population trends of murres and kittiwakes showing declines at Chisik Island and increases at Gull Island.

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel		$11.0
Travel		$1.2
Contractual		$37.0
Commodities		$4.1
Equipment		$0.4
Subtotal	$0.0	$53.7
General Administration		$4.2
Project Total	$56.2	$57.9
Full-time Equivalents (FTE)		0.4
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

	Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		
	$45.0	$0.0	$0.0		

Dollar amounts are shown in thousands of dollars.

Comments:

FY 99

Prepared:

Project Number: 99338
Project Title: Survival of adult murres and kittiwakes
Agency: U.S. Geological Survey

FORM 3A
TRUSTEE
AGENCY
SUMMARY

FY 99 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 1999
vacant	Biotech	GS-5	2.5	2.2		5.5
vacant	Biotech	GS-5	2.5	2.2		5.5
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		5.0	4.4	0.0	
					Personnel Total	$11.0

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 1999
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
					0.0
				Travel Total	$1.2

FY 99

Prepared:

Project Number: 99338
Project Title: Survival of adult murres and kittiwakes
Agency: U.S. Geological Survey

FORM 3B
Personnel
& Travel
DETAIL

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed
Description	FY 1999
Air charter Homer-Chisik (RT) (6 x $500/trip)	3.0
Boat charter (Camp support; Homer-Chisik RT 2 x $1500/trip)	3.0
Safety training	1.0
Research Work Order or euivalent (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**	$37.0

Commodities Costs:	Proposed
Description	FY 1999
Fuel (resighting from water, 15d @ 20gal/day @ $3.00/gal)	1.0
Misc. supplies	1.4
Color bands (300 sets per species per island)	1.2
Metal bands (300 per species per island)	0.5
Commodities Total	$4.1

FY 99

Prepared:

Project Number: 99338
Project Title: Survival of adult murres and kittiwakes
Agency: U.S. Geological Survey

FORM 3B
Contractual & Commodities DETAIL

FY 99 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

New Equipment Purchases:	Number	Unit	Proposed
Description	of Units	Price	FY 1999
Pelican case	2	0.2	0.4
			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**	$0.4

Existing Equipment Usage:	Number	Inventory
Description	of Units	Agency
Boston Whaler (camp and personnel support; @ $75K)	1	FWS
Laptop computer (@ $1.5K)	1	USGS
Zodiac inflatables (2 x $7.5K)	2	USGS

FY 99

Project Number: 99338
Project Title: Survival of adult murres and kittiwakes
Agency: U.S. Geological Survey

FORM 3B
Equipment
DETAIL

Prepared:

Prince William Sound Human Use and Wildlife Disturbance Model

Project Number:	99339
Restoration Category:	General Restoration & Habitat Protection
Proposer:	Chugach National Forest
Lead Trustee Agency:	USFS
Cooperating Agencies:	ADNR
Alaska SeaLife Center:	No
Duration:	2nd year, 2 year project
Cost FY99:	$ 70.1 K
Geographic Area:	Western Prince William Sound
Injured Resources/Service:	ALL (emphasis on: harbor seal, pigeon guillemot and 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 *Exxon Valdez* 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 recovery. Identification of potential areas of disturbance will allow development of recommended management practices that may eliminate or minimize the negative effects of increasing human use. All injured resources and subsistence species will be addressed in a general approach but specific management recommendations will be developed for harbor seal, pigeon guillemot and cutthroat trout. The model of projected human-use patterns and resulting management recommendations are expected to be useful to Federal, State, and private land managers in their land management planning efforts.

INTRODUCTION

In late December, 1997, the EVOS Trustee Council approved funding for a pilot project to develop a model of human use and wildlife disturbance in Western Prince William Sound (PWS). The 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. 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. Identify management actions for public lands 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 benefiting 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.

In FY98 a draft GIS (Geographic Information System) model of existing human use patterns in western PWS is being developed. Obtaining data for this model has been a collaborative effort with tremendous support from the Whittier Harbor, Charter Operators and others. An initial draft model will be completed by May and model verification will begin using aerial survey techniques throughout the summer. This proposal describes the work to be accomplished in Fiscal Year 99.

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. Richardson et al. (1995) 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

This pilot project has focused on western PWS. The project will benefit all State and Federal agencies with management responsibilities in PWS. The project will 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 have been 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

These methods are identical to those described in the original project proposal (98339).

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 FY99

Oct. 1-Dec 15:	Analyze survey data; evaluate and adjust the existing use model
Oct. 1–Jan 31:	Synthesize literature on disturbance into draft management recommendations
Feb. 15–March 15:	Prepare preliminary results for presentation at 10th Anniversary Symposium
March 23-27:	Attend 10th Anniversary Symposium
Jan 1 – May 1:	Identify future use projections and apply to model
May 1:	Finalize management recommendations
April 1 – July 1:	Prepare final report and model

B. Project Milestones and Endpoints

Three objectives were identified for this 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

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 and adjust the existing use model
Oct. 1–Jan 31:	Synthesize literature on disturbance into draft management

	recommendations
Feb. 15–March 15:	Prepare preliminary results for presentation at 10th Anniversary Symposium
March 23-27:	Attend 10th Anniversary Symposium
Jan 1 – May 1:	Identify future use projections and apply to model
May 1:	Finalize management recommendations
April 1 – July 1:	Prepare final report and model

C. Completion Date

This pilot project will be completed in 1999 and we anticipate submitting the final report before its required due date of April 15, 2000. 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 final report for this project will be completed in July 1999. The principal investigators hope to submit the results of this project for publication in FY99 or FY00.

PROFESSIONAL CONFERENCES

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. In addition to these on-going restoration efforts, if the Trustee Council chooses to update the NOAA environmentally sensitive area maps for PWS, the GIS layers from this project would be available for the mapping effort and the digital information on resource concentration areas would be easily incorporated into this model.

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.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

This proposal has changed from the original project proposal submitted for FY98 in two areas: cost and schedule. Because approval of this project was delayed until late December 1998, the schedule was rearranged to reflect the loss of three months during the model development stage of the project. This delay resulted in greater than anticipated costs to expedite data collection and processing in order to have a draft model of existing use completed by May 1998. The delay also results in a delay in the project completion date by three months. This delay means that we need to prepare a separate annual report and final report. Because the original completion date corresponded with the annual report date, only one report preparation period was included in the original budget. The revised budget reflects this additional time commitment and scheduled bi-annual salary increases. It also reflects a higher salary cost for the ADNR employee working on this project. When the initial budget was developed, an individual had not yet been identified and the budget estimate was low for salary costs in FY98.

PROPOSED PRINCIPAL INVESTIGATORS

Karen A. Murphy
Chugach National Forest
Glacier Ranger District
P.O. Box 129
Girdwood, AK 99587
(907) 783-3242

Lowell H. Suring
Chugach National Forest
3301 C Street Ste 300
Anchorage, AK 99503
(907) 271-2836
(907) 271-3992 (FAX)

PRINCIPAL INVESTIGATORS

Lowell H. Suring

Lowell H. Suring received his M.S. in wildlife science from Oregon State University in 1974. His thesis involved assessing habitat use and activity patterns of the endangered Columbian white-tailed deer. This work lead to co-authorship of two major scientific publications. Lowell was leader of the Endangered Species and Wildlife Biometrics units in New York State from 1974 through 1977. In 1977 and 1978 he conducted research on secondary succession patterns in pinyon-juniper woodlands in northwest Colorado. From 1978 to 1984 Lowell held biologist positions with the Fish and Wildlife Service and Forest Service in New Mexico and Minnesota where he was involved with determining wildlife habitat relationships and the assessment of effects of management actions on wildlife habitats and populations. Since 1984, Lowell has been a primary participant in the development of GIS-based wildlife habitat relationships and cumulative effects models in the Alaska Region of the Forest Service. Lowell's professional expertise and interests focus on analyzing habitat-use patterns of wildlife and the development and application of computer-based habitat assessment techniques. He has authored or co-authored more than 30 technical and semi-technical articles describing accomplishments in these areas. Currently, Lowell is employed by the Chugach National Forest where he is implementing analytic techniques and tools that may be used to evaluate the capability of habitats to support wildlife and the effects of land management activities on habitat capability. To support these efforts he has had extensive training and experience in the application of ESRI's ARC/INFO geographic information system. Lowell will have primary responsibility in development of the human use dispersion model.

Karen A. Murphy

Karen Murphy received a Masters in Environmental Management from Duke University in 1995. Her thesis emphasis was on applying decision theory and risk assessment to wildlife management. Karen has extensive experience with fish and wildlife management on the Chugach National Forest. She began working in Alaska in 1984 as a biological technician responsible for conducting field surveys and monitoring in PWS, Copper River Delta and other areas of the Chugach National Forest. In 1991, she began working with the EVOS Restoration Planning Work Group. She participated in the development of the EVOS Restoration Plan and companion EIS. Since 1996, Karen has been the wildlife biologist for the Glacier Ranger District which covers western PWS and Turnagain Arm. Her current position, combined with her EVOS experience will enhance the opportunity to integrate this project with other EVOS projects and to apply the results to wildlife management on the Chugach National Forest. Karen will have primary responsibility for administering and coordinating this project and for the development of management recommendations.

OTHER KEY PERSONNEL

Ali Iliff, Natural Resources Manager who works for ADNR represents the Division of Lands and the Division of State Parks and Outdoor Recreation on this project.

LITERATURE CITED

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1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999	PROPOSED FY 1999 TRUSTEE AGENCIES TOTALS					
			ADEC	ADF&G	ADNR	USFS	DOI	NOAA
					$15.0	$55.2		
Personnel	$0.0	$57.5						
Travel	$0.0	$4.0						
Contractual	$0.0	$0.0						
Commodities	$0.0	$0.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$124.6	$61.5		Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		
General Administration	$14.6	$8.7						
Project Total	$139.2	$70.2		$0.0	$0.0	$0.0		
Full-time Equivalents (FTE)	0.0	0.9						
	Dollar amounts are shown in thousands of dollars.							
Other Resources	$0.0	$0.0		$0.0	$0.0	$0.0		

Comments:

1999

Prepared: 1 of 13

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Lead Agency: US Forest Service

FORM 2A
MULTI-TRUSTEE
AGENCY
SUMMARY

4/15/98

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999						
Personnel		$44.5						
Travel		$4.0						
Contractual		$0.0						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$105.8	$48.5		Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		
General Administration	$12.2	$6.7						
Project Total	$118.0	$55.2						
Full-time Equivalents (FTE)		0.7						
			Dollar amounts are shown in thousands of dollars.					
Other Resources								

Comments:

1999

Prepared: 2 of 13

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3A
TRUSTEE
AGENCY
SUMMARY

4/15/98

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 1999
K.Murphy	Project Co-leader	GS-9	4.5	4.5		20.3
L.Suring	Project Co-leader	GS-12	3.9	6.2		24.2
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		8.4	10.7	0.0	
					Personnel Total	$44.5

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 1999
Travel to GIS and/or The Wildlife Society Conferences	1.0	2	10	0.2	4.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$4.0

1999

Prepared: 3 of 13

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3B
Personnel
& Travel
DETAIL

4/15/98

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed FY 1999
Description	
Commodities Total	$0.0

1999

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3B
Contractual & Commodities DETAIL

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

New Equipment Purchases:	Number of Units	Unit Price	Proposed FY 1999
Description			
			0.0
			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 of Units	Inventory Agency
Description		

1999

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: US Forest Service

FORM 3B
Equipment
DETAIL

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel		$13.0
Travel		$0.0
Contractual		$0.0
Commodities		$0.0
Equipment		$0.0
Subtotal	$18.8	$13.0
General Administration	$2.4	$2.0
Project Total	$21.2	$15.0
Full-time Equivalents (FTE)		0.2
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

	Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		

Dollar amounts are shown in thousands of dollars.

Comments:

1999

Prepared: 6 of 13

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3A
TRUSTEE
AGENCY
SUMMARY

4/15/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 1999
A.Iliff	Natural Resource Manager	16	2.0	6.5		13.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		2.0	6.5	0.0	
					Personnel Total	$13.0

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 1999
					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

1999

Prepared: 7 of 13

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Personnel
& Travel
DETAIL

4/15/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed FY 1999
Description	
Commodities Total	$0.0

1999

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Contractual & Commodities DETAIL

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 - September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
			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

1999

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Equipment
DETAIL

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

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

Comments:

1999

Prepared: 10 of 13

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3A
TRUSTEE
AGENCY
SUMMARY

4/15/98

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 1999
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						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 1999
					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

1999

Prepared: 11 of 13

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Personnel
& Travel
DETAIL

4/15/98

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed FY 1999
Description	
Commodities Total	$0.0

1999

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Contractual & Commodities DETAIL

1999 EXXON VALDEZ TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 1998 - September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
			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

1999

Project Number: 99339
Project Title: PWS Human Use and Wildlife Disturbance Model
Agency: ADNR

FORM 3B
Equipment
DETAIL

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

Project Number:	99340
Restoration Category:	Monitoring
Proposer:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cooperating Agencies:	none
Alaska SeaLife Center:	no
Duration:	2nd year, 4-year project
Cost FY 99:	$86,000
Cost FY 00:	$62,700
Cost FY 01:	$66,600
Geographic Area:	Resurrection Bay/Gulf of Alaska shelf
Injured Resource/Service:	All organisms and services

ABSTRACT

The 28-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 better resolve 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 *Exxon Valdez* oil spill, and it will aid in the design of a long-term, cost-effective ecosystem monitoring program for this shelf.

INTRODUCTION

This is a continuation proposal describing the second of a proposed four-year program to maintain the existing 28-year time series of conductivity–temperature versus depth (CTD) data collected at hydrographic station GAK1 on the north central Gulf of Alaska shelf. The first year's efforts began in November 1997 with monthly cruises to station GAK1. Thus, while the first year's collection and analysis has just begun, it has been instrumental in documenting the evolution of the anomalous ocean warming that began in the summer of 1997 and continues to the present. We have, for example, documented that the anomalous summer warming (amounting to 1–2°C above normal) was confined to the upper 40 m of the ocean. We propose to continue the monthly sampling which shows that, to date (March 1998), the abnormally warm water extends throughout the 250 m depth of the shelf water column. Temperatures are 1.5–2°C above normal, with these anomalies being the largest encountered within the GAK1 time series. We will continue this time series by monthly CTD sampling to provide vertical profiles of temperature and salinity, extending from the surface to the bottom, and hourly samples 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 complement the goals of the Gulf of Alaska component of the U.S. Global Ocean Ecosystem Dynamics program (GLOBEC), which began in October 1997. 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 began in the Gulf of Alaska in October 1997, with modeling and process studies to follow 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 compose 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.) Royer's 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 sea birds (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 included 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 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 in Figure 6, which shows 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 U.S. Global Ocean Ecosystem Dynamics program, began in the fall of 1997 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 Trustee-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 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.

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.

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 the internet. The monthly CTD data will be combined with the existing historical data that are on the Institute of Marine Science webpage, http://www.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. These 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. (Aliasing results when the system or process is undersampled such that the real period or wavelength of the sampled phenomenon is not detected or it is misinterpreted as occurring at a longer period or wavelength.) 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 provide 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 (U.S. 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-foot *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 have 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, 50, 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 are 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 to 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 purchased one mooring in FY 98 and will purchase 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 composes; 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 in the coastal 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 multivariate 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 wind measurements 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 webpage. Atmospheric pressure for correcting sea level is collected from a weather package at the Seward Marine Center.

SCHEDULE

A. Measurable Project Tasks for FY 99 (October 1, 1998 – September 30, 1999)

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 data become available from PFEG
November–December:	Deploy mooring (the mooring will be deployed as soon as instruments can be delivered from the manufacturer) during this month's CTD sampling
September:	If FY 00 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 1999 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. In the past, the final CTD data have generally been 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 it is begun.

If the mooring is recovered in September 1999, all objectives will be reached by early April 2000. If the mooring is recovered in November 1999, all objectives will be reached by early June 2000. Similar analyses and schedules will occur for each year of support. Comparison of the results among 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 99. Data and results will be provided via internet as indicated above.

PROFESSIONAL CONFERENCES

Conference presentations will be made in FY 99, probably at a national meeting such as that of the American Geophysical Union.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

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 U.S. oceanographic community and the North Pacific Marine Science Organization [PICES] composed of marine scientists from around the Pacific Rim). Though we have discussed in previous sections how we would make these data available, 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 (Coyle, Paul, Haldorson, Whitledge, Weingartner) along with Royer (Old Dominion University) have funding from the NSF NOAA GLOBEC program to examine the Gulf of Alaska shelf ecosystem for the period October 1997–December 2000. This work includes 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 (37 over the duration of the GLOBEC program) 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 with other investigators. For example, we have offered berth space on the *Alpha Helix* during our GLOBEC cruises to Robert Day of Alaska Biological Research, Inc., Fairbanks, for his sea bird and marine mammal studies. (Dr. Day is submitting a proposal to the Trustee Council for this project.) Thomas Kline of the Prince William Sound Science Center participated in the first GLOBEC cruise and plans to participate in this year's cruises also.

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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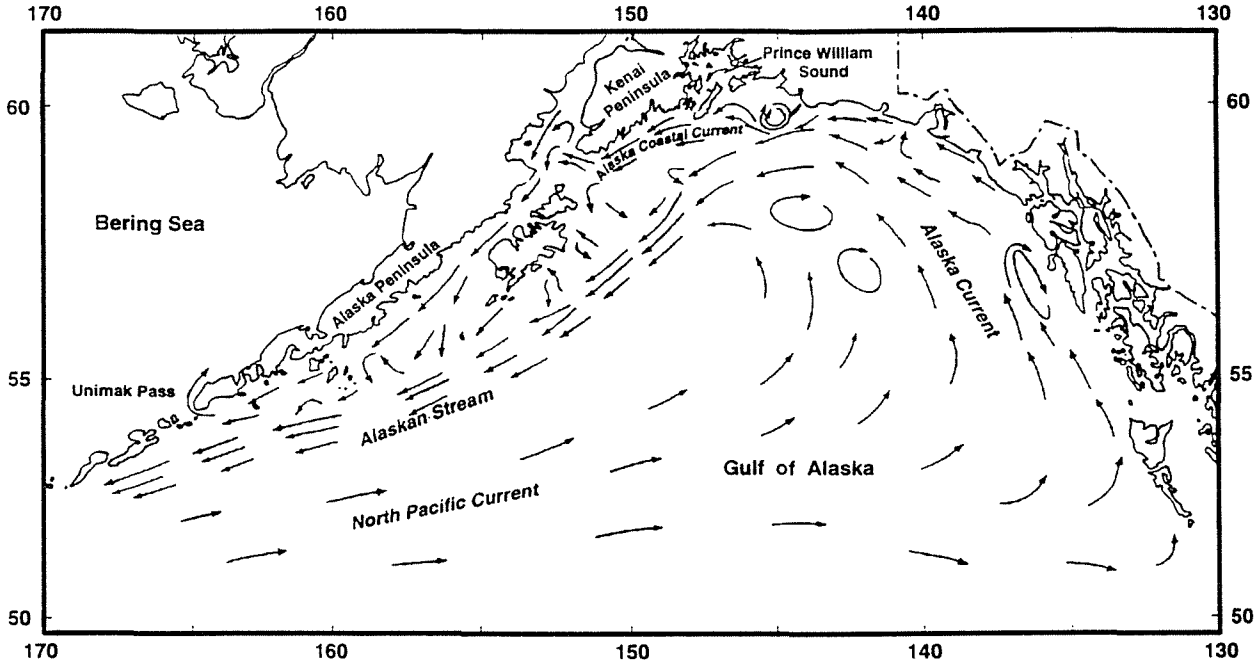

Figure 1. Schematic of the circulation of the Northeast Pacific and Gulf of Alaska (From Reed and Schumaker, 1986).

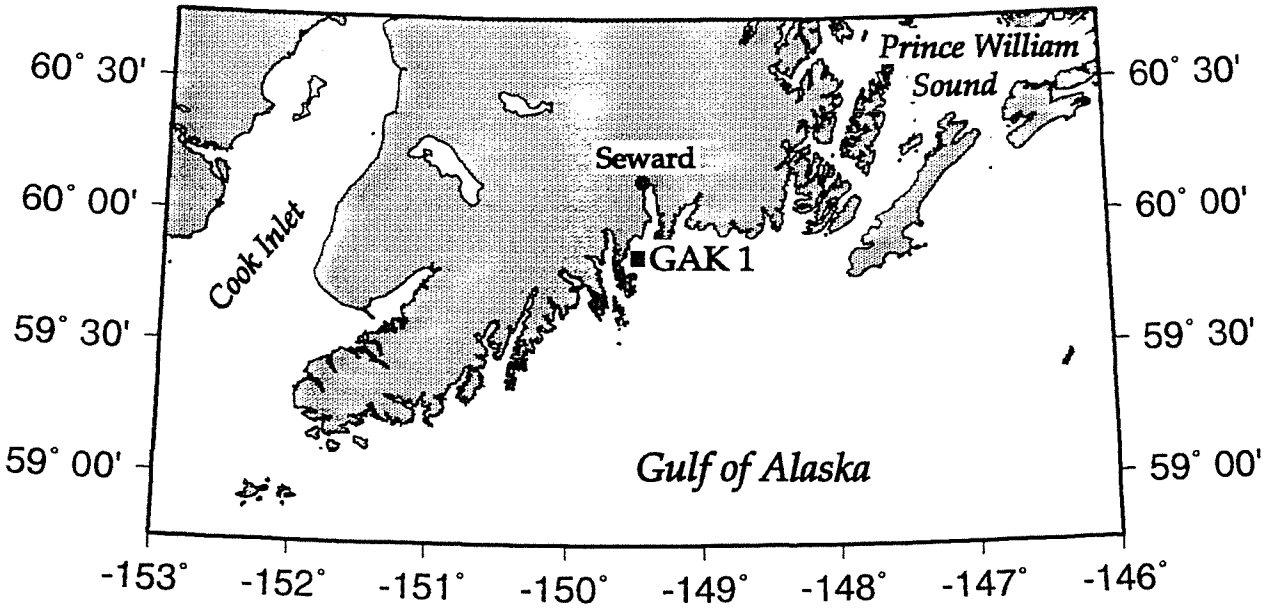

Figure 2. Map showing location of hydrographic station GAK1 in relation to Prince William Sound, Cook Inlet and Seward.

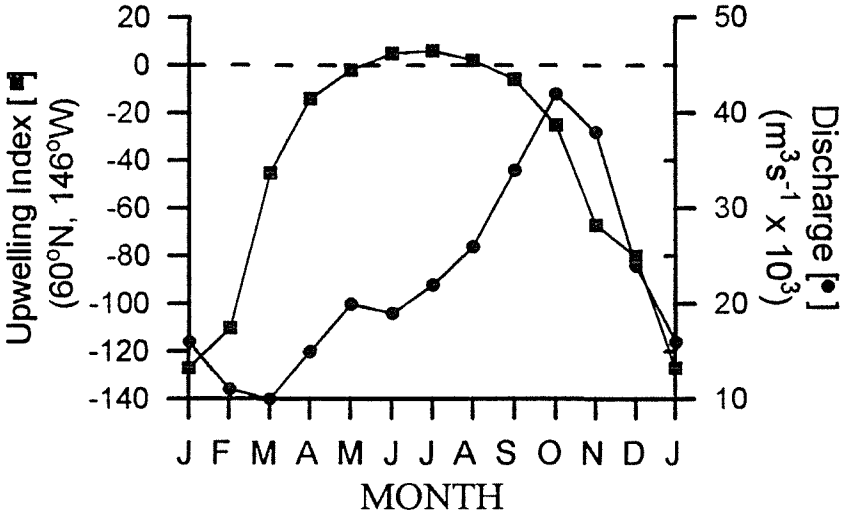

Figure 3. Mean monthly values of the upwelling index (from 1946–1995) and the estimated freshwater discharge (from 1930–1992) into the Gulf of Alaska using the hydrology model of Royer (1982).

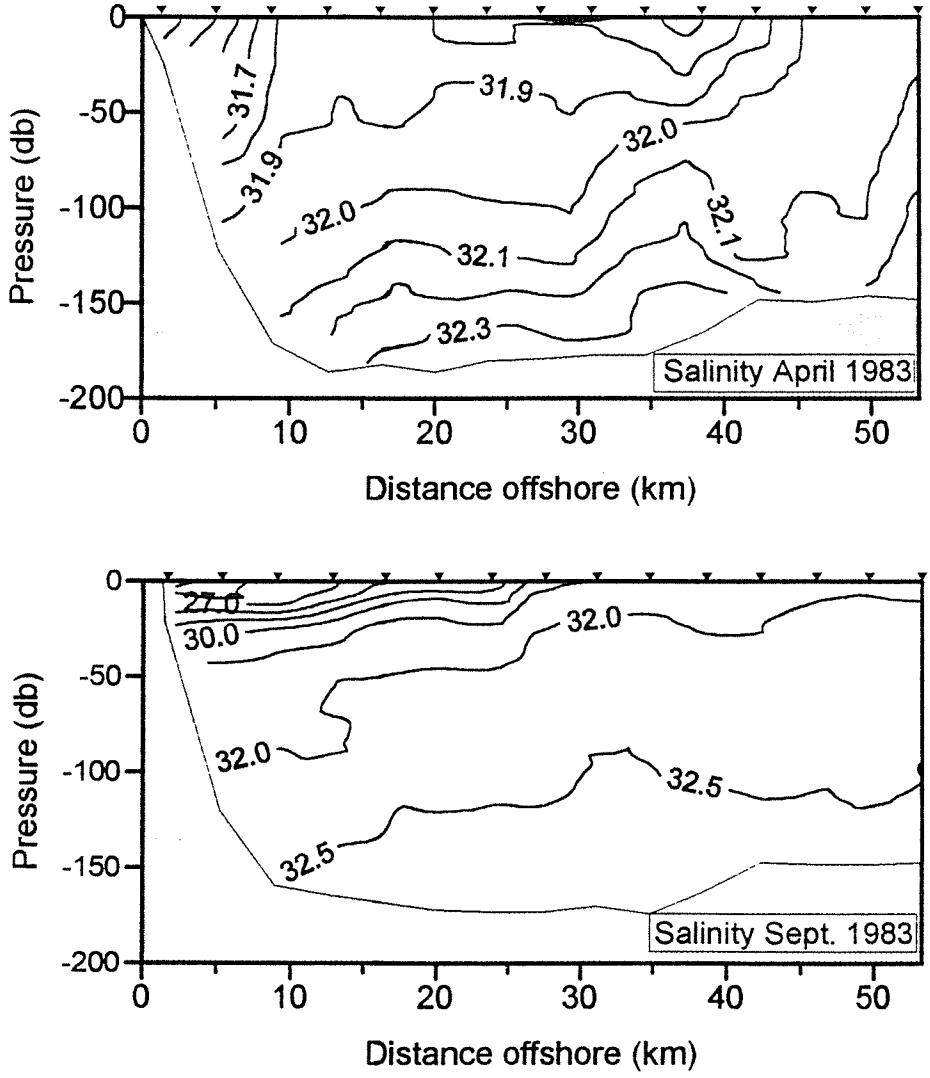

Figure 4. Contours of salinity as a function of depth and position in the Gulf of Alaska on a cross-shelf transect near GAK1. The upper panel is from April 1983 and the lower panel is from September 1993.

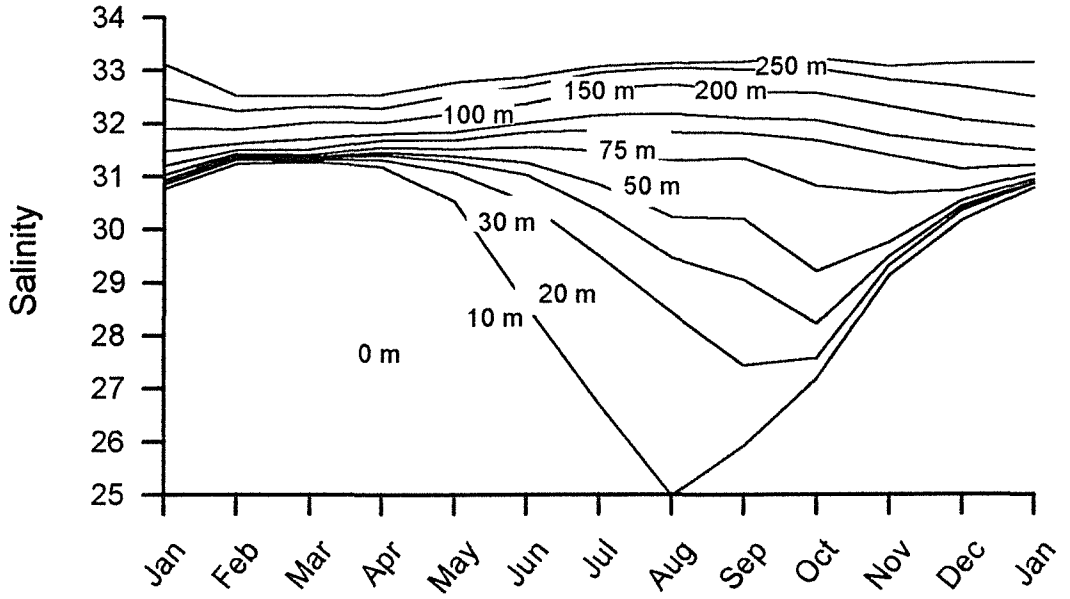

Figure 5. Mean monthly salinity at GAK1 as a function of depth. The means are computed from data collected between 1970 and 1996.

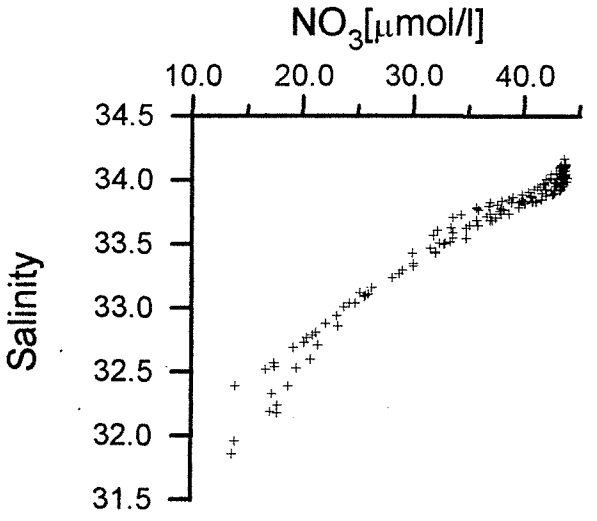

Figure 6. NO_3–salinity scatter plot from the shelf and slope of the northwest Gulf of Alaska in May–June 1993.

PRINCIPAL INVESTIGATOR

Thomas J. Weingartner

EDUCATION

Ph.D. Physical Oceanography, 1990, North Carolina State University
M.S. Physical Oceanography, 1980, University of Alaska
B.S. Biology, 1974, Cornell University

MEMBERSHIPS

American Geophysical Union; American Meteorological Society

PUBLIC SERVICE

Member, Science Steering Committee, NSF – Arctic System Science–Ocean Atmosphere Ice Interaction (OAII) component.
Member, Science Steering Committee, NSF – ARCSS–OAII Shelf–Basin Initiative
Member, Science Steering Committee, NSF – ARCSS–Human Dimensions of the Arctic component
Member, UNOLS – Fleet Improvement Committee
Member, Partners in Science Program with the Fairbanks North Star Borough School District

PROFESSIONAL EXPERIENCE

Assistant Professor; Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks 11/93–present
Research Associate; Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks; 9/91–10/93
Postdoctoral Student; Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks; 7/88–8/91
Graduate Research Assistant; Department of Marine, Earth and Atmospheric Sciences, North Carolina State University; Raleigh, North Carolina; and Department of Marine Science, University of South Florida; St. Petersburg, Florida; 8/84–10/88

PROFESSIONAL INTERESTS

Physical oceanography of the Arctic and North Pacific Ocean and the adjacent shelves, biophysical linkages in oceanography; public education.

PUBLICATIONS

Weingartner, T.J., D.J. Cavalieri, K. Aagaard, and Y. Sasaki. Circulation, dense water formation and outflow on the northeast Chukchi Sea shelf. In press *J. Geophys. Res.*
Weingartner, T.J. A review of the physical oceanography of the Chukchi Sea. Pp. 40–59, *In*: J. Reynolds, editor. Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, MD, 1997.
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Weingartner, T.J. and R.H. Weisberg. 1991. A description of the annual cycle in sea surface temperature and upper ocean heat in the equatorial Atlantic. *J. Phys. Oceanogr.* 21: 83–96.

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Weisberg, R.H. and T.J. Weingartner. 1988. Instability waves in the equatorial Atlantic Ocean. *J. Phys. Oceanogr.* 18: 1641–1657.

Weisberg, R.H. and T.J. Weingartner. 1986. On the baroclinic response of the zonal pressure gradient in the equatorial Atlantic Ocean. *J. Geophys. Res.* 91: 11717–11725.

MANUSCRIPTS IN PREPARATION

Weingartner, T.J., A. Proshutinsky, S. Danielson, Y. Sasaki, V. Pavlov, Y. Kashino, and M. Kulakov. Autumn conditions in the Siberian Coastal Current in the Chukchi Sea.

Weingartner, T.J., K. Aagaard, D.J. Cavalieri and Y. Sasaki. Winter baroclinic processes on the northeast Chukchi Sea shelf

Weingartner, T.J., K. Aagaard, and Y. Sasaki. Circulation in Barrow Canyon and implications on shelf–basin exchange.

Weingartner, T.J. and A. Münchow. Summer conditions in the East Siberian Sea: the enigma of arctic coastal currents.

OTHER KEY PERSONNEL

Dave Allen is the technician responsible for the design and deployment of the mooring.

Phyllis Shoemaker is the Seward-based marine technician who will conduct the monthly CTD sampling from the *Little Dipper*. Both are employees of the Institute of Marine Science.

Mark Vallarino is the programmer responsible for data processing.

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Royer, T.C., J. Vermisch, T.J. Weingartner, H.J. Niebauer, and R.D. Muench. Ocean circulation influence on the *Exxon Valdez* oil spill. *Oceanogr. Soc.* 3: 3–10, 1990.

Stabeno, P.J., R.K. Reed, and J.D. Schumacher. The Alaska Coastal Current: continuity of transport and forcing, *J. Geophys. Res.* 100: 2477–2485, 1995.

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1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 – September 30, 1999

Budget Category:	Authorized FY 1998	Proposed FY 1999
Personnel	$22.8	$35.5
Travel	$3.1	$3.0
Contractual	$6.1	$4.2
Commodities	$1.9	$1.9
Equipment	$23.8	$30.2
Subtotal	$57.7	$74.8
Indirect	$14.4	$11.2
Project Total	$72.1	$86.0
Full-time Equivalents (FTE)	0.3	0.5
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

Dollar amounts are shown in thousands of dollars.

Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		
$62.7	$66.6			

Comments:

The indirect rate is 25% TDC, as negotiated by the *Exxon Valdez* Oil Spill Trustee Council with the University of Alaska.

FY 99

Project Number: 99340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4A
Non-Trustee
SUMMARY

Prepared: 4/12/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1998 – September 30, 1999

Personnel Costs: Name	Position Description		Months Budgeted	Monthly Costs	Overtime	Proposed FY 1999
Weingartner, T.	Principal Investigator/Asst. Professor		1.0	7.0		7.0
Vallarino, M.	Programmer		2.5	5.1		12.8
Shoemaker, P.	Marine Techician		1.0	4.7		4.7
Allen, D.	Technician		1.8	4.6	2.6	10.9
	Adjustment to recognize rounding					0.1
	Subtotal		6.3	21.4	2.6	
					Personnel Total	$35.5

Travel Costs: Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FY 1999
Fairbanks to Seward – research	0.4	2	10	0.1	1.8
Fairbanks to Anchorage – EVOS annual meeting	0.3	1	5	0.1	0.8
Adjustment to recognize rounding					0.4
				Travel Total	$3.0

FY 99

Project Number: 99340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4B Personnel & Travel DETAIL

Prepared: 4/12/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 – September 30, 1999

Contractual Costs:	Proposed FY 1999
Description	
CTD calibration	0.6
Shipping of instrumentation	0.3
MicroCat calibrations (6 @ $500/ea)	0.3
Vessel use (R/V *Little Dipper*) (6 days @ $500/day)	3.0
Contractual Total	$4.2

Commodities Costs:	Proposed FY 1999
Description	
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 99

Project Number: 99340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4B
Contractual & Commodities DETAIL

Prepared: 4/12/98

1999 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1998 – September 30, 1999

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 1999
Seabird Electronic SBE 37 SM with pressure sensor	1	4.4	4.4
Seabird Electronic SBE 37 SM (5 @ $3,155/ea)	5	3.2	16.0
Edgetech BACS 8202 acoustic release	1	10.0	10.0
Adjustment to recognize rounding			-0.2
Those purchases associated with replacement equipment should be indicated by placement with an R.		**New Equipment Total**	$30.2

Existing Equipment Usage: Description	Number of Units

FY 99

Project Number: 99340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: University of Alaska Fairbanks

FORM 4B
Equipment
DETAIL

Prepared: 4/12/98