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19.11.02

RIVER OTTERS AND FISHES IN THE NEARSHORE ENVIRONMENT: A SYNTHESIS

Project Number:	~~02xxxx~~ 02593
Restoration category:	Research
Proposers:	University of Alaska Fairbanks
Lead Trustee Agency:	ADF&G
Cooperating Agencies:	
Alaska SeaLife Center:	No
Duration:	1st year, 2 year project
Cost FY02:	$134,209
Cost FY03:	$30,900
Cost FY04:	None
Geographic Area:	Prince William Sound
Injured Resource:	River otters - Recovered, Intertidal fishes, Pelagic fishes.

ABSTRACT

This project is designed to integrate data collected on river otters and fishes in Prince William Sound (PWS), Alaska, through efforts of the NVP, APEX, and SEA programs. Social organization and population dynamics of river otters, specialized fish-predators, are dependent on abundance and availability of fishes. We propose to critically test the dependence of sociality in river otters on the availability of schooling fishes, the contribution of intertidal/demersal fishes to the diet of solitary otters, and synthesize the data on the effects of fish distributions on otter sociality with that on the effects of social communication of otters on nutrient transports from sea to beach-fringe forests.

INTRODUCTION

In this proposal, funding is requested for conducting an integrative analysis of data collected in both NVP and SEA projects to explore the relation between river otter (*Lontra canadensis*) sociality and landscape use, and spatial and temporal variation in the abundance of forage and intertidal/demersal fishes. We expect to generate at least three manuscripts through this effort. We will critically test the dependence of river otter sociality on the availability of schooling fishes (e.g., herring - *Clupea pallasi*, capelin -*Mallotus villosus*, sand lance - *Ammodytes hexapterus*, and salmon - *Oncorhynchus sp.*) using data collected by APEX and SEA researchers on annual, seasonal, and spatial changes in distribution of forage fishes and data on spatial distribution and variation in sociality of river otters collected by NVP researchers. We will explore the relations between abundance and spatial distributions of intertidal/demersal fishes and their contribution to the diet of solitary otters (including reproductive females) using dive data and fecal and stable isotope analysis conducted by NVP researchers. Finally, we will synthesize these NVP, SEA and APEX data with previously analyzed data on otter energetics (Captive Otter Project 348), population dynamics (NVP), and the role of otters in nutrient transports from sea to land (NVP) to derive a conceptual predictive model that will address the potential effects of climate change on river otters and fishes in the nearshore environment in PWS.

Background

Sociality in river otter

River otters inhabiting coastal environments forage in the intertidal and subtidal zones for marine fishes and invertebrates (Ben-David et al. 1998; Bowyer et al., 1994). Coastal river otters in Prince William Sound (PWS), Alaska, USA, exhibit high variability in social organization. Recent studies documented the occurrence of solitary individuals (Blundell et al., 2000; *in press a*), concurrent with the existence of large groups of up to 18 individuals (Blundell et al., 2000; *in press a*; Rock et al., 1994; Testa et al., 1994). In addition, scent marking at communal latrines (Ben-David et al. 1998; Bowyer et al., 1995; Testa et al., 1994), and helping behavior have been reported in this population (Rock et al., 1994).

Our recent studies demonstrated that male otters exhibited higher degrees of sociality compared with females and occurred more often in same-gender groups. In contrast, females occurred more often in mixed gender groups (Fig. 1; Blundell et al., *in press a*). We were able to determine that social groups of otters were not kin based (i.e., animals did not tend to associate more with kin; Fig. 2; Blundell et al., *in review a*) and that sociality did not result in greater indirect reproductive success for river otters (through increasing reproductive success of kin; Fig. 3; Blundell et al., *in review a*). Similarly, we did not find a relation between degree of sociality and direct reproductive success for either male or female otters (Fig. 4; Blundell et al., *in review a*). Although we were limited in our ability to evaluate the hypothesis that sociality in river otters was an anti-predator adaptation because of difficulties in assessing the risk of predation by marine mammals (e.g., killer whale - *Orcinus orca,* and sea lions - *Eumetopias jubatus*), our data indicated that otters were more social during periods with lower predation risk (Blundell et al., *in press a*).

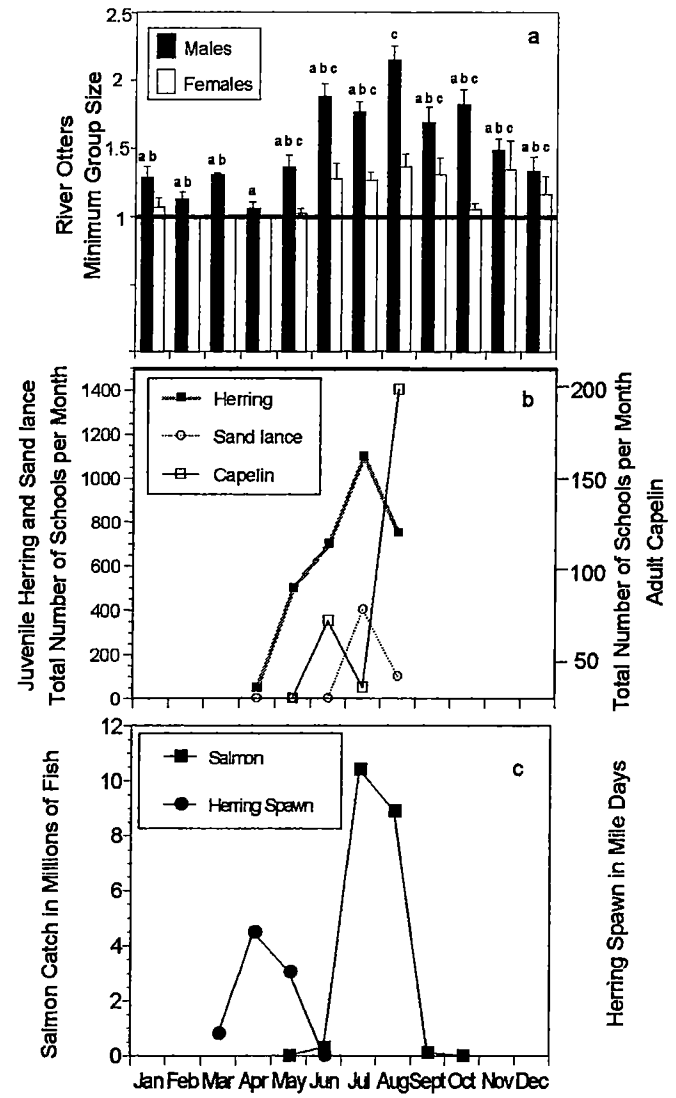

Figure 1 – Mean minimum size of groups for river otters inhabiting Prince William Sound, Alaska from 1996 to 1998 (top) in relation to availability of surface schools of pelagic fishes in the nearshore environment (middle; adapted from Brown et al., 1999), and the period of salmon availability (bottom) in southcentral Alaska and Prince William Sound (adapted from Groot and Margolis, 1991) and herring spawn measured in miles of aerial transects (ADF&G unpublished data, E. Brown pers. comm.). Seasonla changes in group-size of otters appear to correlate with the abundance of schooling fishes.

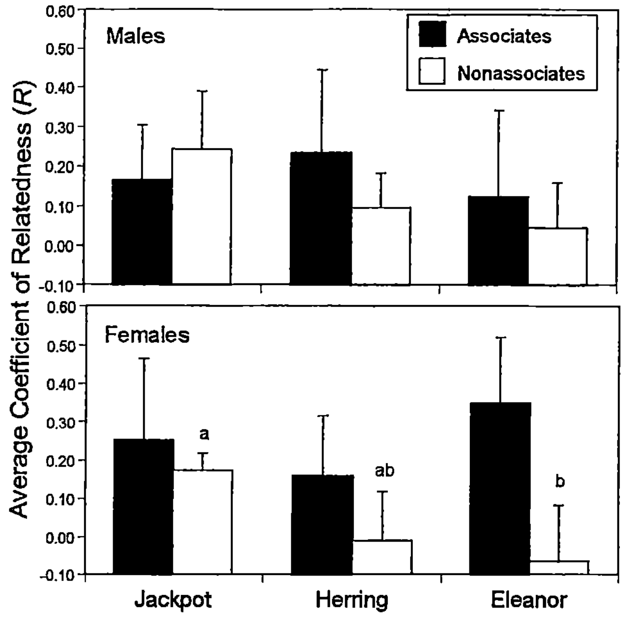

Figure 2 – An assessment, by gender, of the average relatedness ($R \pm$ SD) of radiotagged otters in Prince William Sound, Alaska (1996-1999) to river otters with which they associated (i.e., associates), compared with relatedness of individuals with which they did not associate (i.e., nonassociates). These data indicate that kinship did not influence group formation in river otters.

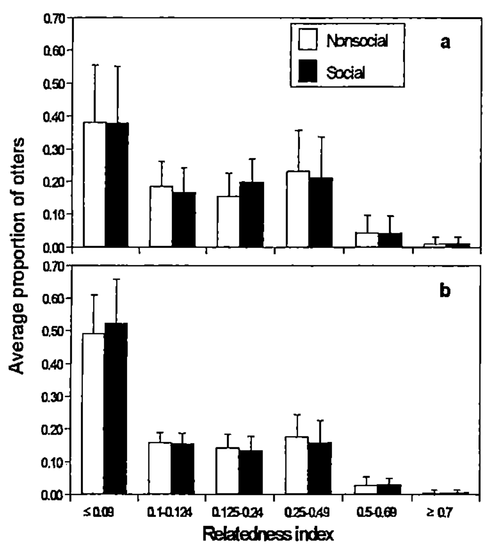

Figure 3 – An evaluation of indirect fitness, comparing the mean proportion ($\pm$ SD) of relatives occurring in each relatedness category, between social and nonsocial otters, in Herring Bay, Jackpot Bay and Eleanor Island (**a**), and among all otters captured in northwestern PWS (**b**). There was no difference in mean proportion of relatives per category between social and nonsocial otters suggesting that social otters did not enjoy indirect reproductive success through their association with relatives.

Our analysis indicated that larger groups of river otters occurred concurrently with availability of schooling pelagic fishes in PWS (Fig. 4; Blundell et al., *in press a*) suggesting that sociality influences foraging success on schooling fishes. Stable isotope analysis revealed that otters that were social in >10% of their locations had diets significantly higher in rapidly swimming pelagic fishes than did less social otters regardless of gender (Blundell et al., *in press a*). In addition, otters that were social >50% of the time had smaller home ranges than did less social otters, and asocial otters had the largest home ranges; an observation that agrees with increased foraging efficiency through cooperative foraging (Blundell et al., *in press a*).

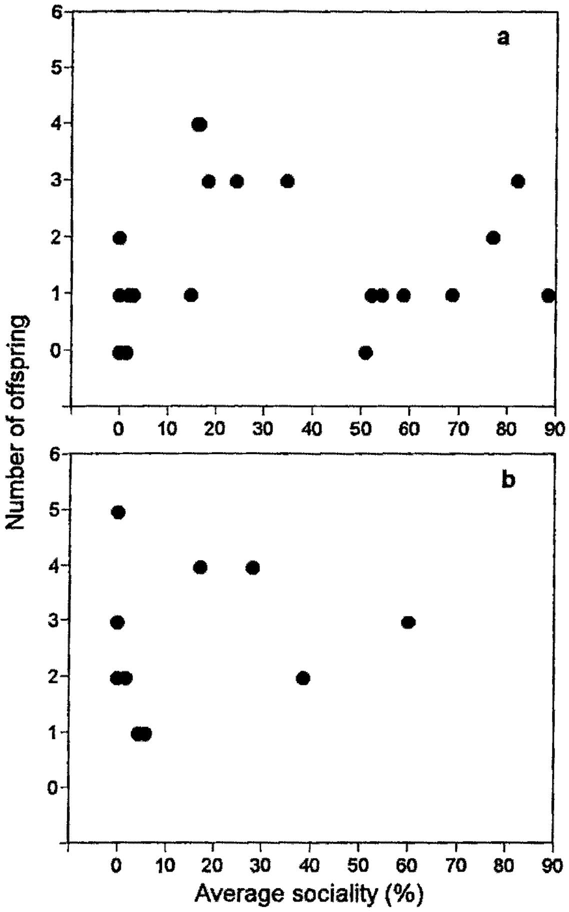

Figure 4 – An evaluation of direct fitness, comparing the degree of sociality (average percent of social locations among all years for each social otter) with the number of offspring for which the otter was identified as a parent. There was no correlation between sociality and number of offspring for male (a) or female otters (b) suggesting that sociality did not translate into higher reproductive success in either gender.

Taken in concert, our data and analyses indicate that sociality in river otters increases foraging success on schooling forage fish. Thus, the abundance and spatial and temporal distribution of these fishes will influence sociality in river otters. This observation is supported by experimental manipulations on captive otters at the Alaska Sealife Center (project 348). In those experiments, foraging success on schooling fishes (e.g., pink salmon) were significantly lower than on intertidal fishes (e.g. kelp greenling) when otters foraged singly, but success dramatically increased when otters were allowed to forage in groups (Fig. 5; Ben-David, unpublished data). These and the stable isotope data indicate that solitary otters will benefit from foraging on intertidal and demersal fishes. The abundance and distribution of intertidal and demersal fishes, therefore, likely will determine spatial distributions and landscape use of solitary otters.

Sociality may be an important factor in determining dispersal patterns and gene flow in river otters. Our data indicated that although males exhibited higher levels of dispersal (including breeding dispersal), females dispersed greater distances, potentially because solitary existence prevents females from settling in neighboring home ranges (Blundell et al., *in review b*). In contrast dispersing males can join multi-male groups in neighboring home ranges. Thus, sociality in otters may influence the ability of otters to recolonize areas in which a catastrophic event (such as the *Exxon Valdez Oil Spill*) may cause extirpation of the local population (Blundell et al., *in review b*).

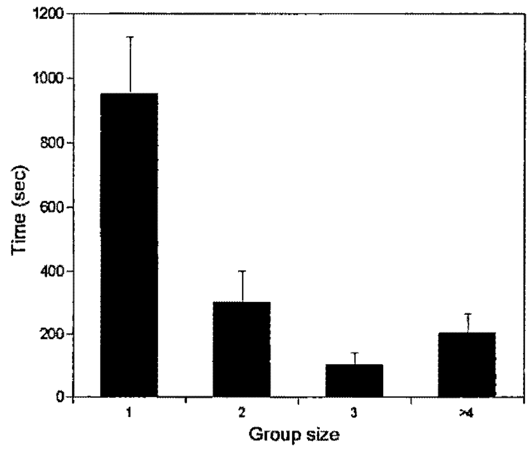

Figure 5 – Effects of group size on foraging efficiency as measured by the time from initiation of foraging to first capture of prey for captive river otters held at the Alaska Sealife Center, Seward, Alaska, USA (Ben-David et al., *in press*). Twelve otters were offered a school of 5 adult pink salmon (*Oncorhynchus gorbuscha*) and allowed to forage individually or in a group for 30 minutes (Ben-David, unpublished data). Increased group size significantly decreased time to first capture indicating increased foraging success.

Although our studies provide strong support for the relation between sociality in river otters and availability of schooling pelagic fishes, a critical test of this relation will require investigation of concurrent changes in spatial and temporal distribution of fish schools and those of otter groups. Data on annual, seasonal, and spatial variation in distributions of schooling fish was collected through efforts of the SEA project. Data on abundance and spatial distribution of intertidal and demersal fishes were collected in the NVP project. Similarly, data on spatial distribution and degree of sociality in river otters were collected by NVP researchers. An integration of these data using spatial and temporal models will provide insight to the mechanisms responsible for the formation of social groups in river otters and offer insights into how such factors will influence natural recolonization of river otter following local extirpation.

Spatial and temporal distribution of schooling fishes in PWS

From 1995 to 1999, information on forage fish distribution was collected using both aerial and acoustic surveys as part of the SEA and APEX programs. Extensive net sampling was included as a part of both acoustic survey programs. The aerial survey data sets include distributions of all surface schooling fish such as herring, sand lance, capelin and eulachon; however, information on juvenile herring and juvenile sand lance dominates the data. Sea bird, shark, jellyfish, and marine mammal distributions are also recorded in the aerial data set. The acoustic data includes mainly herring and pollock, although there were some summer feeding adult capelin and sand lance schools documented in certain regions. The APEX acoustic/net sampling data also includes information about rockfish and sharks.

Methodology for the aerial surveys conducted for this project was developed in 1995-1996 and documented beginning in 1997 (Brown and Norcross 1997; Brown and Borstad 1998; Brown 1998; Brown et al., submitted) under the Sound Ecosystem Assessment (SEA) project. Broadscale measurements of forage fish distribution and abundance in PWS, the GOA inner shelf, and the OK were completed for June and July 1995-1997. In 1995-1996, other months were sampled. A broadscale survey was a single pass over most of the PWS coastline. In 1996-7, fine scale and repeat measurements were taken for a subset of herring nursery bays in eastern, northern, southwestern and central PWS in addition to the broadscale survey measurements. For the APEX project, a single broadscale survey was conducted in July, 1998 and 1999. In addition, we conducted daily, repeat surveys (n = 15) over the three APEX study regions in PWS (Northern, Central and Southwest), which represented the foraging range of two Black-legged kittiwake colonies (Shoup Bay and Eleanor) as well as the study sites for APEX and NVP Pigeon Guillemot and APEX Marbled Murrelet projects.

Acoustic survey design, and thus data available, varied temporally and spatially between SEA and APEX. The study objectives varied as well; detailed studies on juvenile herring were the focus for SEA, whereas APEX was tasked with a broader task of documenting distribution and fisheries oceanography of all available forage fish species (during sea bird reproductive periods). For the SEA project, three broadscale acoustic surveys covering much of the nearshore (< 1 km) region of PWS were conducted in October 1995, March 1996, and July 1996. Starting in 1996, four representative herring nursery bays were selected; each representing a region (eastern, northern, southwestern and central) of PWS where juvenile herring were abundant. Temporally stratified (day and night; spring, summer, and fall) acoustic surveys were conducted in each of the four bays. For APEX, three broadscale acoustic surveys were completed annually during the fall (October or November), late spring (May) and mid-summer (July) starting in the fall of 1994 to the summer of 1997. From 1995 to 1996, both offshore and nearshore areas were surveyed. From 1998 to 1999, July was the only month surveyed and oceanography was dropped from the study objectives. Acoustic data collected prior to 1999 was scaled improperly. A supplemental fund was provided to this project to complete the rescaling of all surveys collected from 1995-98. In addition, APEX data was reprocessed and binned to enable comparisons with the SEA data. The combined SEA/APEX acoustic data will be incorporated into a single database. Raw data files were assembled and edited by Brown and Moreland; while the algorithms to rescale the data were developed by Dr. Ken Coyle (UAF) according to Thomas and Kirsch (1999). The rescaling was completed in November, 2000.

The combined aerial/acoustic data will be "fused" and organized in bin groupings this summer as part of the APEX closeout work (Brown and Moreland 2000). This will entail normaliztion for the differences in spatial coverage, creating 3-D arrays of horizontal and vertical distribution, and clustering the acoustic data to identify schools. Each bin group created will be geocoded and thus perfectly suited for spatial analysis. This project will use the data set created for the APEX synthesis product.

Abundance of intertidal and demersal fishes in PWS

Abundance of intertidal and demersal (nearshore) fishes in PWS was estimated in an effort to determine differences in prey availability for river otters between oiled and nonoiled areas (Bowyer et al. *in review*). Fishes were sampled by SCUBA divers at 30 latrine sites used by otters in oiled and nonoiled areas in July 1996-97, as well as at 30 random sites at each location in both years. All fishes counted were classified into 3 size classes (<8 cm, 8-15 cm, >15 cm total length) and were identified to 8 categories: the perciformes – ronquils (Bathymasteridae), pricklebacks (Stichaeidae), and gunnels (Pholidae); as well as families in other orders, including cods (Gadidae), rockfishes (Scorpaenidae), sculpins (Cottidae), greenlings (Hexagrammidae), and other. While this data was invaluable in the determination of the status of recovery of river otters (Bowyer et al., *in review*), evaluating the data in relation to diet of otters (obtained through fecal and stable isotope analyses – conducted by G. M. Blundell and M. Ben-David) can be instrumental in obtaining a better understanding of spatial distributions of otters, especially those solitary individuals. Additional information on abundance of intertidal and demersal nearshore fishes in PWS are available in Rosenthal et al. (1982), Barber et al. (1995), Laur and Haldorson (1996), and Dean et al. (2000).

The role of otters in transporting nutrients from sea to land

Evaluation of the relation between abundance and distribution of fishes and that of river otters has an additional significance beyond that of the species-specific processes. As part of their social behavior, river otters mark specific locations along the coast with feces, urine, and anal gland excretions (Ben-David et al., 1998). Known as latrine sites, these areas are typically 10 - 50 m in radius and 25 - 300 m apart (ca., 160 latrines/100 km of shoreline). The distribution of latrine sites along the coast is dependent on several habitat variables related mainly to features of the intertidal zone, such as tidal slope and rock size (Ben-David et al. 1996; Bowyer et al., 1995). Direct observations suggest that visitation rate to latrine sites is high and occurs up to 9 times during a single activity bout (Testa et al., 1994; M. Ben-David pers. obs.). Calculations of the amount of nitrogen transported by river otters from sea to land, based on population densities, N consumption and excretion, and spatial area of latrines, resulted in an estimate of 15.7kg/ha/year (Ben-David, unpublished data). Nonetheless, because latrine site use appears to relate to social male-male communication (Fig 6., R. Rostein and M. Ben-David, unpublished data), the daily input of N per unit area of coastline will not only depend on the number of animals on the landscape and their visitation rates to latrine sites, but also on the demography of the population (female/male ratios), the degree of sociality of males, and the reproductive success of female otters.

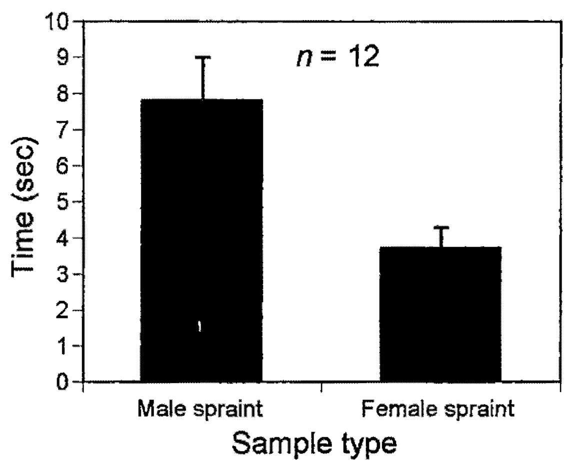

Figure 6 - Scent marking experiments on captive river otters conducted at the Alaska Sealife Center in Seward, indicated that male river otters spent more time investigating foreign male feces than investigating foreign female scent, suggesting that this behavior may be related to male-male communication (R. R. Rostein, unpublished data). This observation agrees well with the observation that males tend to be more social than females in this species (Blundell et al., *in press*).

Using stable isotope analysis Ben-David et al. (1998) determined that plants growing in river otter latrine sites had significantly higher values of $\delta^{15}N$ compared with the same conspecifics collected from random sites representing the incorporation of marine derived nitrogen from otter excretions (Fig. 7; Ben-David et al., 1998). Although the responses of the vegetation to fertilization by river otters require additional investigation, preliminary results indicate that few plants growing on latrine sites have elevated N content, and that plant community differed between latrine and non-latrine sites (Ben-David et al., 1998).

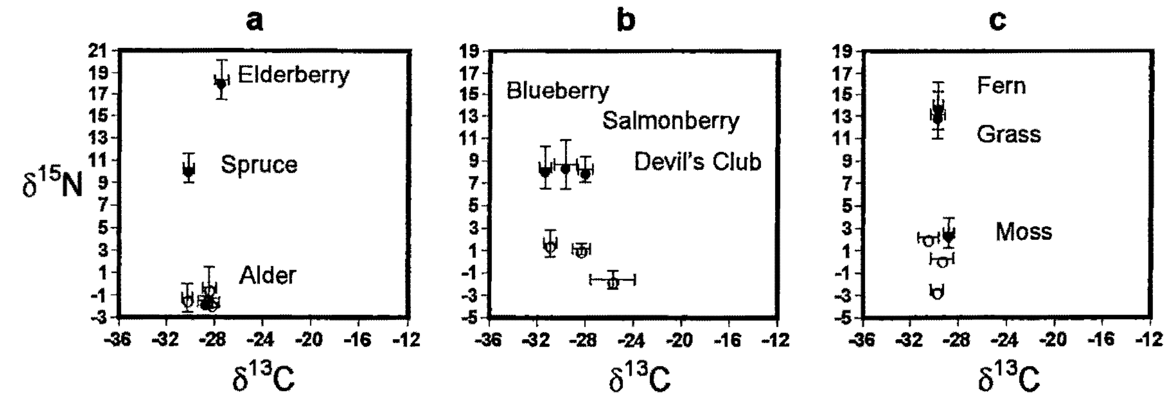

Figure 7 - Stable isotope values (mean ± SE) for leaf buds of trees (a); leaf buds of shrubs (b); and herbs (c) collected in Prince William Sound and Kachemack Bay, Alaska, in early May 1994 and 1996. Closed symbols represent samples collected from river otter latrine sites, whereas open symbols represent samples collected from non-latrine sites. Sample sizes range between 4 and 10 specimens (Table 1). Because alder derives most of its nitrogen from the atmosphere via N fixation it served as control in this study. Adapted from Ben-David et al. (1998).

These data indicate that sociality and social communication in river otters can have significant influence on landscape heterogeneity in the land-margin ecosystem. Therefore, a synthesis of the data on the relation between spatial and temporal distributions of fishes and river otter sociality, with previously analyzed data on otter energetics (Captive Otter Project 348; Ben-David et al., 2000; Ormseth and Ben-David, 2000; Williams et al., *in prep*), population dynamics (NVP), and the role of otters in nutrient transports from sea to land (NVP) will result in a conceptual predictive model that will address the potential effects of climate change on fishes, river otters and terrestrial forests in the land-margin ecosystem in PWS.

NEED FOR THE PROJECT

A. Statement of Problem

As specialized fish-predators, river otters are dependent on abundance and availability of fishes and thus may act as a window to the spatial and temporal changes in fish distributions in the nearshore environment in PWS. Our recent explorations indicated that large groups of otters, composed mainly of males, occur concurrently with the nearshore migration of herring, capelin, sand lance, and salmon. In contrast, when forage fish are absent from the system river otters consume more intertidal and demersal fishes, and the degree of sociality declines. A critical test of the dependence of otter sociality on the availability of schooling fishes, the contribution of intertidal/demersal fishes to the diet of solitary otters (including reproductive females), and a synthesis of the effects of fish distributions on otter sociality and their role in nutrient transports to the beach-fringe forests can be achieved through integration of the wealth of data collected during previous phases of the NVP and SEA projects. This project is designed to integrate data collected on river otters in PWS through the NVP project and that on fishes collected in the NVP and SEA programs.

B. Rationale/Link to Restoration

Effective implementation of the *EVOS* Trustee Council's policy that "Restoration should contribute to a healthy, productive and biologically diverse ecosystem...", is complicated by the diversity and trophic interdependence of the numerous injured resources within the nearshore system. A synthesis of the data on the relation between spatial and temporal distributions of fishes and river otter sociality, with previously analyzed data on otter energetics (Captive Otter Project 348), population dynamics (NVP), and the role of otters in nutrient transports from sea to land (NVP) will result in a conceptual predictive model that will address the potential effects of climate change on fishes, river otters and terrestrial forests in the land-margin ecosystem in PWS. Such integration of data collected in different projects funded by the Trustee's Council as part of the Restoration program will maximize benefits from these efforts and provide baseline information for evaluation of future changes in the environment (whether natural or human induced).

C. Location

Data analysis and report writing will be conducted in Fairbanks Alaska and Laramie Wyoming. Investigators will travel between these locations as required.

COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

This project involved intensive data collection both in Prince William Sound, the Alaska Sealife Center as well as in the different laboratories. We have recruited local high school, undergraduate and graduate students to assist in the data collection. We have interacted with local communities and presented our findings to community members and the general public. Additional presentations will be organized in the future.

PROJECT DESIGN

A. Objectives

The objectives for FY02 are to complete data analyses, writing of 3 manuscripts, and publication of results.

B. Methods

Data analysis on fish distributions and availability and river otter distribution and social organization will be conducted with GIS tools and appropriate mathematical and statistical models.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

This project is a collaborative research project of scientists from two university research centers and several laboratories (University of Alaska - Institute of Marine Sciences; University of Alaska - Institute of Arctic Biology – Spatial Ecology Laboratory; and the University of Wyoming). University of Alaska Fairbanks will be responsible for the research work order, and contracts to the University of Wyoming.

Professional services contracts and Research Work Order mechanisms will be used to transfer funds from Trustee Agencies to university and cooperators on this project.

SCHEDULE

A. Measurable Project Tasks for FY 00

This project will begin in October 2001 and will be completed in September 2003.

October – December 2001: Complete spatial analyses of spatial and temporal data of fishes and otters
January 2002: Attend Annual Restoration Workshop
January – September 2002: complete writing of manuscripts and submit for publication
Summer 2002: Attend the meeting of the Ecological Society of America.
October 2002 - September 2003: finalize publication of manuscripts.

B. Project Milestones and Endpoints

FY 02: Data analysis and submission of 3 manuscripts
FY 03: Finalize publication of manuscripts

C. Completion Date

The work will be completed by Sept. 2003.

PUBLICATIONS AND REPORTS

Publications to be submitted by September 30, 2002:

1. Blundell, G. M., E. D. Brown, M. Ben-David, and S. C. Jewett. Forage fishes and river otter sociality: variation in spatial and temporal distributions. To be submitted to *Ecology*.

   This manuscript will address the hypothesis that river otter sociality depends on the availability of schooling fishes. This hypothesis will be critically tested using data collected by SEA researchers on annual, seasonal, and spatial changes in distribution of forage fishes and data on spatial distribution and variation in sociality of river otters collected by NVP researchers. Analysis will require spatial modeling with GIS tools.

2. Blundell, G. M., M. Ben-David, and S. C. Jewett. River otters as a window to the nearshore environment. To be submitted to the *Journal of Mammalogy*.

   This manuscript will explore the relation between abundance and spatial distributions of intertidal/demersal fishes and their contribution to the diet of solitary otters (including reproductive females) using SCUBA transect data and fecal and stable isotope analysis conducted by NVP researchers.

3. Blundell, G. M., S. C. Jewett, E. D. Brown, R. T. Bowyer, and M. Ben-David. River otters and fishes in the nearshore environment: a synthesis. To be submitted to *Ecological Monographs.*

   In this manuscript we will synthesize the data from the two above listed manuscripts with previously analyzed data on otter energetics (Captive Otter Project 348; Ben-David et al., 2000; Ormseth and Ben-David 2000; Williams et al., *in prep*), population dynamics (NVP; Bowyer et al., *in review*), and the role of otters in nutrient transports from sea to land (NVP; Ben-David et al., 1998) to derive a conceptual predictive model that will address the potential effects of climate change on river otters and fishes in the nearshore environment in PWS.

PROFESSIONAL CONFERENCES

The senior scientists on this project will present project results at various forums in 2002 including the annual *EVOS* meeting in January in Anchorage and the Ecological Society of America meeting.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project is designed to integrate data collected on river otters (*Lontra canadensis*) in Prince William Sound (PWS) through the NVP project and that on fishes collected in the NVP and SEA programs.

PRINCIPAL INVESTIGATOR

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Stephen C. Jewett, Ph.D., has been at the School of Fisheries and Ocean Science, University of Alaska Fairbanks, since 1974. He currently serves as Research Professor. During this time he has been involved in numerous benthic and intertidal investigations throughout Alaska that emphasize assessment and/or monitoring. He has authored or coauthored more than 40 publications in scientific journals and books. He has been the coordinator of the federal/state EVOS shallow subtidal investigations in Prince William Sound (1989-2000). Most recently he was a co-principal investigator on the NVP study, focusing on intertidal and nearshore fishes and invertebrates. His responsibility will include project coordination, data analyses, and report writing.

OTHER KEY PERSONNEL

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Merav Ben-David, Ph.D. is an Assistant Professor in the Department of Zoology and Physiology, University of Wyoming. She has studied river otters in Prince William Sound since 1991 and has extensive experience in studying behavior of mammals and birds. Her research concentrates on the influence of animal behavior on ecosystem processes. She is an affiliated member of the IUCN/SSC otter specialist group. Most recently she was the principal investigator on the Captive River Otter Study (348), and affiliated with the NVP project. Her responsibilities in this project include data analysis and report writing.

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Gail M. Blundell defended her Ph.D. thesis on March 23, 2001. She conducted research on river otters in Prince William Sound as project leader for the river otter component of NVP. While collecting and analyzing data relative to NVP hypotheses, she also conducted her doctoral research with an emphasis on behavioral ecology (gender differences in ecology, dispersion of individuals relative to prey resources and reproductive opportunities), spatial relationships (effects of relatedness on social organization and dispersion), and patterns of gender-biased dispersal and gene flow. She is an affiliated member of the IUCN/SSC otter specialist group. She will be the PI responsible for data analyses and report writing.

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Evelyn D. Brown, PhD candidate, has been with the University since 1995 as a research associate, working for the Alaska Department of Fish and Game for over 10 years prior to that. She has focused studies on Pacific herring (retrospecitve, stochastic modeling of recruitment), forage fish distribution and ecology (spatial analyses), and is currently working on development of airborne remote sensing tools for the marine ecological and fisheries research. This year, she will be completed a synthesis analysis of environmental factors affecting forage fish distribution in PWS and that same data set will be used for this study. Her responsibility on this project will be providing the SEA/APEX data and assisting with spatial analysis of fish distribution and publications.

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John Kern has extensive experience in analyzing spatial data and knowledge of statistical modeling. He has been involved in data analysis of data collected through the NVP, SEA, and APEX projects. He will provide advice on data analysis. No funding is requested for Kern as he will be funded through other sources.

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UNIVERSITY OF WYOMING

Vice President for Research
P.O. Box 3355
Laramie, Wyoming 82071-3355
(307) 766-5353 • (307) 766-5320
FAX (307) 766-2608

April 5, 2001

University of Alaska-Fairbanks
Institute of Marine Sciences
Fairbanks, AK 99775

Re: Proposal to be submitted to the Exxon Valdez Oil Spill Trustees Council
"River Otters and Fishes in the Nearshore Environment: A Synthesis"

UAF PIs: Stephen C. Jewett, Gail M. Blundell, Evelyn D. Brown
Institute of Marine Sciences
UW PI: Merav Ben-David, Department of Zoology and Physiology

We have reviewed the proposal which will be submitted to the EVOS Trustees Council by the University of Alaska-Fairbanks. The proposed budget for Wyoming's participation appears to be adequate to fund the activities proposed and is approved for submittal.

The appropriate programmatic and administrative personnel of the University of Wyoming are prepared to establish the necessary inter-institutional agreement(s) if the proposal is funded by the granting agency.

Please feel free to contact me if I can provide any additional information.

Sincerely,

Roger Wilmot
Associate Vice President for Research

2002 *EXXON VALDEZ* TRUS[illegible] COUNCIL PROJECT BUDGET
October 1, 200[illegible] - [illegible]eptember 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$0.0						
Travel		$0.0						
Contractual		$134.2						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$134.2	Estimated FY 2003					
General Administration		$9.4						
Project Total		$143.6						
Full-time Equivalents (FTE)		1.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY02

Prepared:

Project Number: 02593
Project Title: River Otter and Fishes in the Nearshore Environment
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2002 *EXXON VALDEZ* TRU! COUNCIL PROJECT BUDGET
October 1, 200ı - ueptember 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$86.2						
Travel		$6.0						
Contractual		$15.1						
Commodities		$0.1						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$107.4	Estimated FY 2003					
Indirect		$26.8						
Project Total		$134.2	$30.9					
Full-time Equivalents (FTE)		1.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

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

FY02

Prepared:

Project Number: 02593
Project Title: River Otter and Fishes in the Nearshore Environment
Name: Stephen C. Jewett

FORM 4A
Non-Trustee
SUMMARY

2002 *EXXON VALDEZ* TRU! COUNCIL PROJECT BUDGET
October 1, 200ı - ʊeptember 30, 2002

Personnel Costs:				Months	Monthly		Proposed
	Name	Position Description		Budgeted	Costs	Overtime	FY 2002
	Jewett, S.	PI/Research Professor		1.0	8.1		8.1
	Blundell, G.	Research Associate		10.0	5.6		56.1
	Brown, E.	Research Associate		2.0	6.5		13.0
	TBA	Technician		2.0	4.9		9.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		15.0	25.1	0.0	
						Personnel Total	$86.2

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 2002
	Fairbanks to Anchorage	300.0	2	6	120.0	1.3
	Fairbanks to Lower '48	1000.0	1	4	120.0	1.5
	Fairbanks to Wyoming	1100.0	2	8	120.0	3.2
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$6.0

FY02

Prepared:

Project Number: 02593
Project Title: River Otter and Fishes in the Nearshore Environment
Name: Stephen C. Jewett

FORM 4B
Personnel
& Travel
DETAIL

2002 *EXXON VALDEZ* TRUS COUNCIL PROJECT BUDGET
October 1, 200 - September 30, 2002

Contractual Costs:	Proposed
Description	FY 2002
Subcontract: University of Wyoming (M. Ben-David)	13.7
Shipping, photocopying	0.4
GIS computer fee	1.0
Contractual Total	$15.1

Commodities Costs:	Proposed
Description	FY 2002
Project supplies	0.1
Commodities Total	$0.1

FY02

Prepared:

Project Number: 02593
Project Title: River Otter and Fishes in the Nearshore Environment
Name: Stephen C. Jewett

FORM 4B
Contractual &
Commodities
DETAIL

New Equipment Purchases:	Number	Unit	Proposed
Description	of Units	Price	FY 2002
			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	
Description	of Units	

FY02

Prepared:

Project Number: 02593
Project Title: River Otter and Fishes in the Nearshore Environment
Name: Stephen C. Jewett

FORM 4B
Equipment
DETAIL

02597-BAA

Ocean Color Time Series of Prince William Sound, Submitted under the BAA

Project Number: 02597-BAA
Resoration Category: Monitoring
Proposer: Oregon State University
Lead Trustee Agency:
Cooperating Agencies:
Alaska SeaLife Center: No
Duration: 1st year 1 year project
Cost FY02: $26.6
Cost FY03:
Geographic Area: Prince William Sound and Alaskan coastal waters
Injured Resource/Service:

RECEIVED
APR 10 2001
EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL

ABSTRACT

A time series of chlorophyll concentrations and other ocean color products will be developed for general use. The time series will include full resolution images of the coastal waters of Alaska and Prince William Sound in particular. SeaWiFS data collected at University of Alaska-Fairbanks will be processed with the current state of the art algorithms. The data will be mapped into regional areas at 1km resolution. We will examine the possibility of adding CZCS and OCTS data to increase the temporal extent of the time series. This data set will allow investigators to examine how the base of the food chain (phytoplankton) has varied monthly, seasonally, and annually during the life of these missions.

INTRODUCTION

We propose to use existing satellite ocean color measurements to develop a monitoring program for primary productivity in Prince William Sound, Cook Inlet, and the Gulf of Alaska. The ocean color measurements can be used to: 1) examine surface chlorophyll concentrations; 2) assess the spatial and temporal variations in the base of the food chain; 3) study the effect of primary productivity fluctuations on higher trophic level organisms; and 4) determine the exchange of phytoplankton between coastal and oceanic regimes. A time series of chlorophyll will be developed using SeaWiFS data and supplemented with Coastal Zone Color Scanner (CZCS 1978-1986) and Ocean Color and Temperature Scanner (OCTS, 1996-1997) measurements when those measurements are available and time permitting.

Time-series measurements allow an understanding of long-term changes in ecosystems, as well as an opportunity to study how physical forcing mechanisms, like local currents affect the biological properties of the ocean. Time series derived from satellite data have the added benefit of high-spatial and high temporal resolution. Ocean color measurements can be used to infer chlorophyll concentrations (Figure 1), sediment loads, and colored dissolved organic material levels. With the increased spectral resolution in the next generation ocean color sensors the capabilities will be increased even further.

To date there have been 3 ocean color satellites that are no longer in service, 7 are presently in service, and 6 more are planned for launch in the near future (http://www.ioccg.org/sensors/500m.html). Ocean color is planned to become an operational resource, like SST, ensuring that products derived from ocean color can be monitored on a long-term basis.

Spatially averaged data is typically available from the sensor project offices. For SeaWiFS some products are available in 4 km Global area coverage (GAC) and 9 km Global gridded forms. The reduced spatial resolution data is not desired for coastal regions where the spatial scales of interest and the proximity of land requires full resolution imagery. The full resolution (1 km for SeaWiFS) processed data not made available by NASA. The processing of full resolution imagery is time consuming. The new iterative-algorithms have increased processing time significantly. We now need 1 to 1.5 months of CPU time to process a years worth of HRTP images from a single station. Many of the algorithms used to derive various products also continue to evolve as more validation data becomes available. Some times the changes involve simple recalculation involving the water leaving radiances and others require full reprocessing of the data. Because of the time involved in processing the data it makes sense to create regional centers that process and maintain data for all users.

Persistent cloud cover is a concern in developing a practical time series for the region. Examining the SeaWiFS data browser (http://seawifs.gsfc.nasa.gov/SEAWIFS.html) shows that quality imagery is available each month except November through January when the sun is too low. Therefore the cloud cover does not appear to prevent a useful time series from being developed. Because of the high latitude location of the study site, satellite overpasses are more common in this region providing multiple opportunities to collect quality data each day.

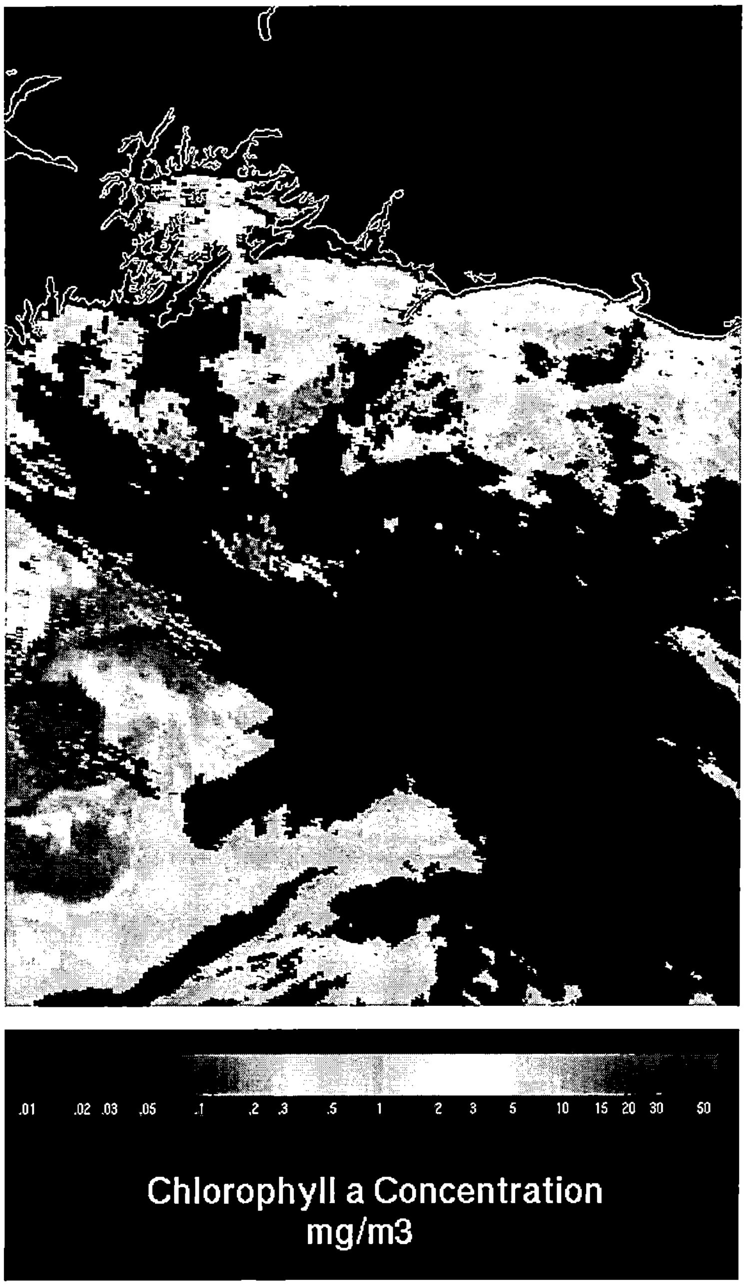

Figure 1. SeaWiFS chlorophyll image of the Prince William Sound region (the hatched area within region 2 of Figure 2). This image was processed by the Optical Oceanography Group at Oregon State University using data collected at MBARI. This region is at the extreme northwestern extent of that receiving site and hence not often sampled by them. The UAF receiving station provides better coverage of the region. The red color is high chlorophyll (phytoplankton) concentrations and blue are low. In Prince William Sound the chlorophyll levels are moderate with some patches of high concentrations. The black portions are clouds and land.

NEED FOR THE PROJECT

A. Statement of the Problem

Studies of the spatial and temporal variability of abundance in higher trophic organisms requires an understanding of the variability in the concentration of organisms at the base of the food chain. The proposed work addresses how the natural variability in phytoplankton concentrations, and hence primary production, may affect restoration efforts. While this proposal does not directly address the injured resources and services listed in Table 4 of the invitation to submit restoration proposals, *it does address a critical basic biological parameter important to all of the listed resources.*

B. Rationale/Link to Restoration

Monitoring the changes in the first level of the food chain is essential in understanding the food resources for higher trophic organisms. The proposed work will set up a location where investigators can access high quality imagery of Prince William Sound and other coastal Alaskan waters in order to study how phytoplankton concentrations vary between years. Investigators can then assess the impact of size and timing of blooms in the region on the survival and fecundity of higher trophic organisms like fish and birds.

As a monitoring project the proposed work will cover several past years of measurements and develop a database that can easily be continued into the future. The processing algorithms for SeaWiFS, OCTS, and CZCS have matured to the point that output is no longer in the developmental stages. We expect that MODIS processing will also mature within the next year. The time consuming portion of the work is in reprocessing existing data. Maintaining the data set requires relatively little effort. If we wait to develop the time series it will require more effort to get the data set current.

C. Location

The work will be conducted at Oregon State University. Prince William Sound and Lower Cook Inlet/Kachemak Bay (hatched region in Figure 3) will be the primary time-series regions. Because remapping the full level 2 image takes little additional effort we will make additional time-series regions to cover the extent of the Alaskan coast.

COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

The proposed web-based image browser will allow people from affected communities to examine the data. I suggest linking our browser through the Exxon Valdez Oil Spill Trustee Council website.

As this proposal only covers processing existing data it does not include a traditional and local knowledge component.

PROJECT DESIGN

A. Objectives

The objective of this proposal is to create and maintain a time-series database of full (~1 km) resolution SeaWiFS ocean color products, including chlorophyll and normalized, water-leaving radiances in Prince William Sound, the Gulf of Alaska, and along the Alaskan coast. We are proposing to process and maintain full resolution SeaWiFS data that is currently being collected at the University of Alaska-Fairbanks receiving station. As time allows we will expand the data set to include measurements from previous satellite missions (CZCS, OCTS) as well as other current sensors (primarily MODIS).

B. Methods

SeaDAS software from NASA will be used to process SeaWiFS data to develop 1-km resolution maps of chlorophyll and water-leaving radiance within Prince William Sound and along the Alaskan coast. The data will be made available to interested investigators electronically.

SeaWiFS full resolution (HRTP) data collected at the University of Alaska receiving station will be processed to level 2 using SeaDAS software and the default processing settings. The use of default settings is to ensure comparability with the GAC products of NASA. The processed level 2 data will cover the extent of the UAF receiving sites range (Figure 2). We will work with personnel from UAF to collect the level 2 data that they process. *Currently this data is not maintained within Alaska.* Archived data from UAF has not been reprocessed with the updated algorithms and UAF does not retain the level 2 data more than a few days. Thus, it will be relatively simple to remain caught up in the data processing, however work will be required to get the time series of level 2 data up to date using the current algorithms. We have developed batch routines for processing SeaWiFS data that allow us to more rapidly processes historical data.

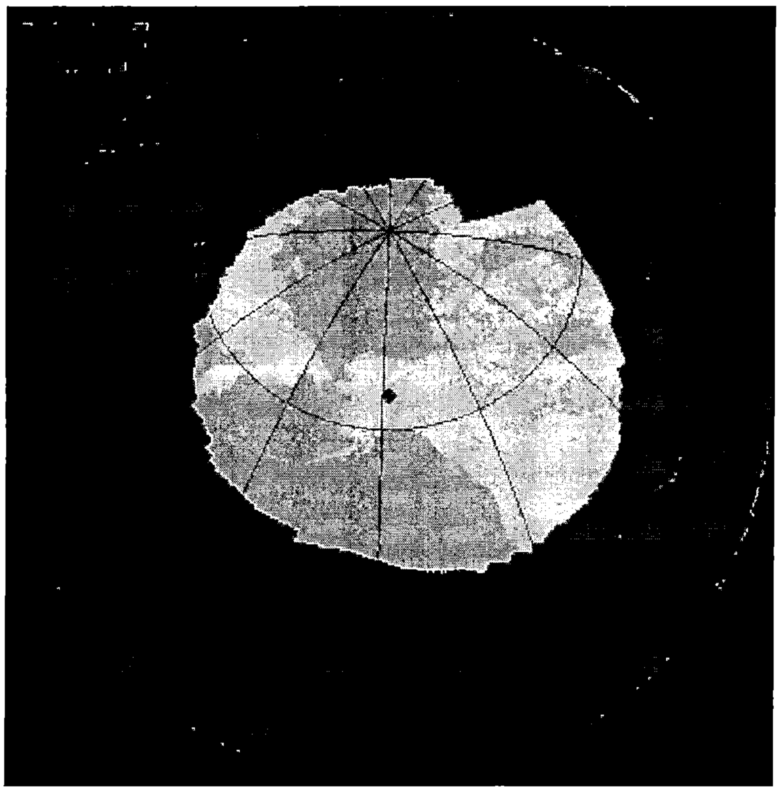

Figure 2. The light area corresponds to the receiving range of the UAF station. We are proposing to only process those passes that include coverage of the Alaskan coastal region.

The level 2 data will be remapped into several smaller regions covering the coastline of Alaska (Figure 3). Once the data processing has been completed, mapping the entire Alaskan coastline requires extremely little extra effort compared to just mapping the Gulf of Alaska region. Any other desired regional maps can be generated easily at this stage as well. The regional data will only be remapped if at least 5% of the ocean area contains chlorophyll estimates. The selection of the regions was based on, 1) keeping the size of regions small enough to allow a user to more easily work with the data, 2) to allow for nearly uniform space-to-pixel sizes within a box, 3) to provide images that were easily viewed on screen, 4) and to cover at least 300 km seaward from land (300 km was chosen to cover the small-scale variability associated with the shallower coastal regions).

We plan on making several products available. The products will include:

- level 2 processed data of chlorophyll and normalized, water-leaving radiances (on tape)
- level 3 regional (1km) SeaWiFS mapped versions of the products (by ftp)
- gif images of the regional data along with a large-region, 5 km resolution gif image of Alaska and the surrounding waters (on web).

The products will not be merged, so if two satellite passes cover the same region we will process both but leave them as separate data files. We anticipate that chlorophyll will be the product in highest demand. By providing the normalized, water-leaving radiances investigators can apply algorithms to determine other products or test new algorithms. If we find that other oceanographic products are in high demand we can use the water-leaving radiance data to quickly provide that product. The gif images will be used to develop a web-based browser so that users can select the data they are interested in.

The products will be accessed in three manners. The gif images will be placed on-line so that they can be browsed by region and date. The data will be maintained at a secure site, as required by Orbimage and the SeaWiFS project office. We will provide a username and password for authorized SeaWiFS users. Researchers can become authorized SeaWiFS users online through the SeaWiFS data archive (http://daac.gsfc.nasa.gov/data/dataset/SEAWIFS/index.html). The filenames will include year, day, time, region number, receiving station, and product. Unmapped level 2 data will be available upon request. That data will be provided on 8 mm tapes.

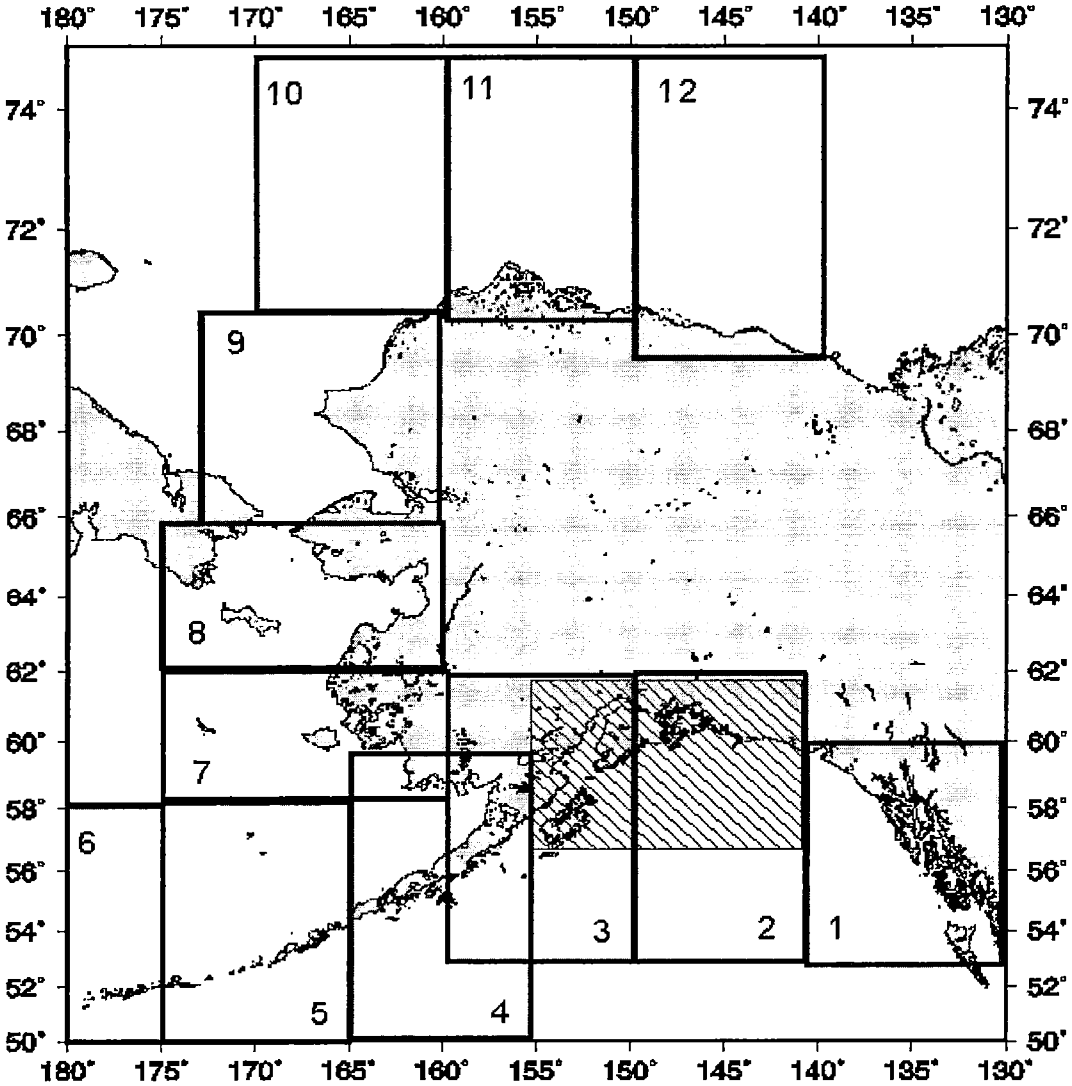

Figure 3. Map of the proposed time series regions. The hatched area is the primary region of interest. The numbered boxes are other regions that the data will be mapped to.

The SeaDAS software program is also capable of processing CZCS and OCTS images. We will thus be able to use the same processing software to process data from the previous ocean color missions. The CZCS data is available through the Goddard DAAC in a manner similar to the SeaWiFS data and we will investigate acquiring OCTS imagery. Processing of data from these previous missions will occur as time allows. The reprocessing of HRTP SeaWiFS data from the UAF receiving station will take at least 3 computer months. Other demands for computer time will limit our ability to reprocess data from previous ocean color missions during the year duration of this proposal.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

None.

SCHEDULE

A. Measurable Project Tasks for FY 02 (October 1, 2001 – September 30, 2002)

November 1:	Aquire UAF HRPT data from Goddard DAAC Place standing order for future data
December 31:	Complete reprocessing of 1997 and 1998 data
January 31:	Complete reprocessing of 1999 data, attend annual restoration workshop
February 28:	Complete preliminary web browser
April 15:	Submit annual report
April 30:	Complete reprocessing of 2000 and 2001 data
May 1 – September 30:	Maintain SeaWiFS data up to date and process CZCS and OCTS data as time allows.
September 30:	Develop links to MODIS to allow that data to be incorporated into the time series, submit final report

B. Project Milestones and Endpoints

April 30, 2002:	Complete developing SeaWiFS ocean color time series and have web browser in place
September 30, 2002:	Data base shifted to maintenance mode and paths for incorporation of data from other ocean color sensors completed.

C. Completion Date

The objectives of the proposed work will be completed within fiscal year 2002.

PUBLICATIONS AND REPORTS

An annual report will be filed in April 2002 and a final report will be provided at the end of FY 2002.

PROFESSIONAL CONFERENCES

No funds are requested for travel to professional conferences.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

We will contact other investigators funded in FY 2002 to ensure they have knowledge of the proposed resource. It is anticipated that this project will be closely integrated with other monitoring efforts like the Sound Ecosystem Assessment work. In particular, we are interested in working with the Katchemak Bay Esturarine Research Reserve to combine our imagery with their surface chlorophyll level monitoring program. Their measurements will act as a source of ground truth data for the imagery.

The equipment and training for data processing was provided under previous NASA SeaWiFS and SIMBIOS support. *Funding for future maintenance of an ocean color data set that includes all of the US Pacific coast will be submitted to NASA.*

PROPOSED PRINCIPAL INVESTIGATOR

W. Scott Pegau
Oregon State University
104 Ocean. Admin. Bldg.
Corvallis, OR 97331
ph: 541 737-5229
fax: 541 737-2064
spegau@oce.orst.edu

PRINCIPAL INVESTIGATOR

W. Scott Pegau has been involved with studies using ocean color in NASA (SeaWiFS and SIMBIOS) and Navy (HyCODE) programs. These efforts include collecting ground-truth measurements, analysis of discrepancies between field and satellite measurements, and development of new algorithms. He has supervised the acquisition and processing of SeaWiFS data for studies in the Gulf of California from the launch of SeaWiFS to this date. He has been the lead or co-author on 17 peer-reviewed publications within the past ten years, with another 9 publications currently accepted.

OTHER KEY PERSONNEL

Francios Baratange will be the technician in charge of processing data and developing a web site for dissemination of the data.

FY 02 *EXXON VALDEZ* TRU[illegible] COUNCIL PROJECT BUDGET

October 1, 200[illegible] [illegible]ptember 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002
Personnel		$15.1
Travel		$1.2
Contractual		$1.8
Commodities		$0.5
Equipment		$0.0
Subtotal	$0.0	$18.6
Indirect		$8.0
Project Total	$0.0	$26.6
Full-time Equivalents (FTE)		0.3
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

Estimated FY 2003					

Dollar amounts are shown in thousands of dollars.

Comments:
The indirect rate is 43% of total direct costs, This is the negotiated rate between OSU and the government
1 week of Pegau is for preparation and attending the annual conference, 1 week of Pegau is for writing the annual and final reports
2 weeks of Pegau are for supervising the technician and interacting with other P.I.s
2 months of technician time are needed to process SeaWiFS data and develop a web based browser for the gif images
Funds are requested to keep one computer connected to the oceanography network to act as web server and data processing
supplies for normal computer use are requested, CD-ROMs and tapes are for distribution of level 2 data

FY02

Prepared: Mar-01

Project Number: 02597-BAA
Project Title: Ocean color time series of Alaskan coastal waters
Name: Oregon State University

FORM 4A
Non-Trustee
SUMMARY

FY 02 *EXXON VALDEZ* TRUS[illegible] COUNCIL PROJECT BUDGET

October 1, 200[illegible] [illegible]eptember 30, 2002

Personnel Costs:				Months	Monthly		Proposed
Name	Position Description			Budgeted	Costs	Overtime	FY 2002
W. Pegau	Principal Investigator			1.0	6.3		6.3
F. Baratange	Technician			2.0	4.4		8.8
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		3.0	10.7	0.0	
						Personnel Total	$15.1

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2002
W. Scott Pegau, Anchorage, Travel to annual meeting	0.6	1	3	0.2	1.2
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$1.2

FY02

Prepared: Mar-01

Project Number:
Project Title: Ocean color time series of Alaskan coastal waters
Name: Oregon State University

FORM 4B
Personnel
& Travel
DETAIL

FY 02 *EXXON VALDEZ* TRU! COUNCIL PROJECT BUDGET
October 1, 200 . ..ptember 30, 2002

Contractual Costs:	Proposed
Description	FY 2002
long distance communication, for telephone communication with other investigators	0.3
OSU computer connection charge, for processing and website maintenance	1.5
Contractual Total	$1.8

Commodities Costs:	Proposed
Description	FY 2002
computer supplies, CD-ROMs, tapes, printer cartriges, etc.	0.5
Commodities Total	$0.5

FY02

Prepared: Mar-01

Project Number:
Project Title:
Name:

FORM 4B
Contractual &
Commodities
DETAIL

New Equipment Purchases:	Number	Unit	Proposed

FY 02 *EXXON VALDEZ* TRU!   COUNCIL PROJECT BUDGET
October 1, 200ı - ᴗeptember 30, 2002

Description		of Units	Price	FY 2002
				0.0
				0.0
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				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	
Description	of Units	

FY02

Prepared: Mar-01

Project Number:
Project Title: Ocean color time series of Alaskan coastal waters
Name: Oregon State University

FORM 4B
Equipment
DETAIL

A synthesis of the ecological findings from the EVOS Damage Assessment and Restoration Programs, 1989-2001

Project Number: 02600

Restoration Category: Monitoring, Research

Proposer: Robert B. Spies, EVOS Chief Scientist, and collaborators

Lead Trustee Agency: Not known

Cooperating agencies: None

Alaska SeaLife Center: No

Duration: 1st year, 2 year project

Cost Fy02: $141.7K

Cost FY 03: $289.1

Geographic Area: No field work

Injured Resource/Service: All resources

ABSTRACT

This project will synthesize the significant results from 12 years of post-spill study in the EVOS damage assessment and restoration programs as they relate to anthropogenic and natural forcing factors influencing the northern Gulf of Alaska. The results of the synthesis will be incorporated into a series of interrelated manuscripts that will either be submitted to a journal for publication as a whole volume, or to a publisher as a book. This effort will be one of the major products of the EVOS restoration program and help set the foundation for the Gulf Ecosystem Monitoring Program.

Introduction

The effort being proposed is a synthesis of the main scientific findings from the EVOS Restoration program, with an emphasis on what new has been learned about the affected ecosystem, particularly the variability in this ecosystem in response to the spill and to natural factors. It will be based on the products of the scientific studies following the spill and will cover the period of 1989 to 2001. Publications, final reports and data from this effort will be evaluated to determine what can learned about human and natural forcing factors in the ecosystem.

Need for the Project

A. *Statement of the problem*--The proposed long-term monitoring and research program for the northern Gulf of Alaska (GEM) is best put in place on a solid foundation from previous intensive work in the ecosystem affected by *the Exxon Valdez* Oil Spill. With over 300 separate research projects that studied virtually all major components in the ecosystem over 12 years, with many simultaneous studies that potentially captured large-scale variability in various ways, and with major ecosystem studies now completed but with minimal interaction between them, the foundation has been laid in the damage assessment and restoration programs for such a synthesis. And, with at least some GEM activities due to start in FY 2003 and to expand slowly over the first 5 years of the program, the time for a synthesis is in FY 2002-2003

Since the occurrence of the spill much has been learned about long-term ecological change in the north Pacific, both due to human activities and due to climate variability. The efforts to ascribe ecological change to particular causes over the last 12 years have been focused on various aspects of the ecosystem and have produced over 300 publications by Trustee Council scientists and an almost equal number form Exxon-sponsored studies. Recent analyses of multiple biological and physical data sets indicate that large-scale climate-induced shifts occurred in the North Pacific in 1977 and 1989 (Hare and Mantua, 2000). Both of these shifts likely had consequences that interacted in unique ways with the massive damage from the *Exxon Valdez* oil spill and the subsequent recovery of the ecosystem.

B. Rationale/link to Restoration--

Beginning in 2003 a new phase of the restoration process will start, long-term monitoring supported by the Restoration Reserve. This monitoring program, the Gulf Ecosystem Monitoring Program (GEM) will have as one of its main goals detection of natural and anthropogenic change in the ecosystem. The program will be based on a conceptual model that describes how the ecosystem works and how it varies with external forcing factors, both natural and human. The program is being designed so that this model will change as our knowledge of the Gulf of Alaska matures and deepens. Ecological insight that can inform this conceptual model will be especially useful in the next several years. The National Research Council (NRC) is conducting a review of the proposed program and plan. One of their main recommendations is to build GEM on a good understanding of what has been learned from the last 12 years. In order to do this the NRC and many scientists familiar with the Restoration Program have suggested that a comprehensive scientific synthesis be performed.

C. Location

There is no field work being proposed for this project. The outcome of this study should contribute substantially to GEM and eventually to a better understanding of the ecosystem on which the coastal communities of the northern Gulf of Alaska depend.

COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

We will interact with regional communities and subsistence users principally in two ways. First, In the first year of the project all of the community facilitators, and the Chugach Regional Resource Commission will be contacted during the information gathering phase of the project. They will be invited to contribute to the synthesis. Secondly, during the completion of the work a multimedia display will be developed to explain the findings of the study in understandable terms and presentations made at those communities that wish to participate.

PROJECT DESIGN

A. Objectives

The project has the following objectives for FY 2002:

1. Gather, read and evaluate the relevant reports, pubications and other modes of information about the changes in the affected ecosystem between 1989 and 2002.

2. Gather any relevant publications and historical data sets and evaluate them in order to understand ecosystem changes that occurred before the spill.

3. Produce an outline of the integrated synthesis.

4. Find a journal willing to publish a dedicated volume, or obtain a publisher for the work as a book and negotiate the terms of a contract.

4. Begin writing the various chapters of the synthesi.

The objectives for FY 2003 include:

1. Complete rough drafts of the component chapters of the integrated synthesis.

2. Exchange drafts among authors for internal review and to revise chapters.

3. Make a multimedia presentation for the public.

4. Obtain outside peer review.

5. Submit synthesis to the publisher.

B. Methods

The methods for conducting this synthesis are those employed in a large scholarly undertaking. They can conveniently be broken down into the following steps:

1. *Gathering the relevant information.* All of the EVOS final reports are in the office of the Chief Scientist, who will serve as Principal Investigator and editor. These reports are also available as PDF reports online at www.dtlcrepository.downlegal.com/ARLIS-/PDF. Many of the publications from the scientific literature are also available in the office of the Chief Scientist or the EVOS Restoration Office in Anchorage. A bibliographies of Trustee- and Exxon-sponsored studies is kept by the EVOS Restoration Office. Publications will be gathered and distributed by administrative staff at Applied Marine Sciences (AMS). ARLIS, the natural resources library in Anchorage, is available to support this phase of the project. AMS also subscribes to Cambridge Scientific Abstracts, an online service that provides literature searches returning full references for publications and their abstracts. Each of the contributing authors will be asked to keep a reference list using Endnote software. These lists will be exchanged between authors and the editor to identify additional literature.

2. *Evaluation.* Each of the contributing authors will read the appropriate reports and examine the appropriate data sets and then evaluate them with regard to anthropogenic and natural forces in ecosystem change.

3. *Chapter outlines.* Each of the authors will produce a preliminary outline and reference list for circulation among the other authors and the editor. These will be reviewed and revised in light of the comments. The outline for the integrated synthesis will then be finalized.

4. *Obtaining a publisher.* The leading marine biological journals will be contacted as well as potential book publishers to determine their interest in the synthesis based on the outline. A publisher will be chosen and negotiations for publications will be undertaken.

5. *Manuscript preparation.* The individual authors will write their chapters based on the outline. The editor will hold periodic conference calls and at least one face-to-face meeting per year will be held.

6. *Initial review.* Draft manuscripts will be exchanged among authors and with the editor during the first part of FY2003 for review.

7. *First revisions.* Review comments from authors and the editor will provide a basis for the first revision. The editor will monitor progress and encourage completion as the deadline for revisions of the drafts approaches.

8. *Independent review.* Outside reviewers will be enrolled to review the revised manuscripts and provide written comments. If a journal is the publication vehicle, then the journal editor can undertake this.

9. *Final revision.* The final revisions will be incorporated and the manuscripts submitted for publication.

C. Organization

The following is a tentative organizational scheme for the effort, which is subject to revision as the authors begin to formulate an outline of subjects:

1. Introduction
2. physical oceanography and climate
3. nutrients and biological oceanography
4. fishes
4. nearshore processes (limited)
6. birds and mammals
5. ecotoxicolgy

A recent major review of shoreline and nearshore impacts of the spill has been completed (Peterson, 2001). So, although we are allocating some additional effort in this area, it will of more limited than other aspects of the synthesis.

D. Cooperating agencies, contracts, and other agency assistance.

The Principal Investigator is an employee of AMS, which is proposed as the prime contractor for production of this synthesis. All of the chapters will be written on fixed price contracts with the authors contracted as consultants to AMS.

SCHEDULE

A. Measurable project tasks for FY2002 and FY2003

December 2001	Preliminary chapter outlines and list of references due
March 2002	Outline finalized
June 2002	Negotiations with a publisher completed
October 2002	Rough drafts of chapters due from authors
December 2002	Completion of internal reviews
January 2003	Outside reviews initiated
March 2003	Outside reviews completed
May 2003	Multimedia presentation completed
July 2003	Revised chapters due to editor
September 2003	Final submission of all chapters to publisher

B. Project milestones (see schedule above)

C. Completion date

The project will be completed in September 2003.

Publication and Reports

A single book-length publication will be produced at the end of the two-year period. The title will be decided at a later date.

Professional conferences

The P.I. requests travel to one professional conference in 2003 to present the results of the synthesis effort and travel expenses to one annual EVOS meeting for each of the authors.

Normal agency management

Not applicable, as none of the authors is from an agency.

Coordination and integration

Coordination will be through the Office of the Chief Scientist working with the staff of the Restoration Office and ARLIS to obtain the materials necessary to complete the proposed work.

Proposed Principal Investigator

Robert B. Spies, Ph.D.
EVOS Chief Scientist
Applied Marine Sciences
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Livermore, CA 94550
Phone (925) 373-7142
Fax (925) 373-7834
e-mail address: spies@amarine.com

Principal Investigator

Dr. Robert B. Spies has a Ph.D. from the University of Southern California (1971). He has over 30 years of expereince in marine science. He has been Chief Scientist to the EVOS Trustee Council since 1990. In that role he has reviewed all of the reports for the many scientific projects conducted following EVOS, conducted numerous workshops to identify gaps in studies of natural resources impacted by the spill, and has reported to the Executive Director and the Trustee Council on the status of the impacted ecosystem on a regular basis. Dr. Spies is also past editor of *Marine Environmental Research* and serves on its Editorial Board. He also serves on the Editorial Board of *Aquatic Toxicology*. He has over 40 publications on marine ecology and ecotoxicology.

Other key personnel

Dr. Thomas Weingartner. Dr. Thomas Weingartner is an observational physical oceanographer on the faculty of the University of Alaska's Institute of Marine Science. For the past twelve years he has conducted research in the seas and

- Check bags at the ticket counter ITM or curbside.
- Go directly to the gate with your government-issued photo ID.

Trip Reminders

- A maximum of two carry-on items are allowed.
- Each carry-on item can measure up to 9 x 14 x 22 inches (23 x 36 x 56 cm).
- Learn more about what items are restricted from baggage.

For On-Time Departures

- Due to Anchorage Airport construction please allow one and one half (1 ½) to two (2) hours. See the Anchorage Airport web site for details.

Prior to Departure	Domestic US	International
Arrive at Airport:	60 minutes prior	90 minutes prior
Reserved seats released:	20 minutes prior	40 minutes prior
Must be seated onboard:	10 minutes prior	30 minutes prior

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To learn how to earn bonus miles and expedite your airport check-in process, click the Check-in button. CHECK-IN oceans surrounding Alaska, including the Gulf of Alaska, Prince William Sound, and the Bering, Chukchi, and Beaufort seas. He is currently a Principal Investigator in the Gulf of Alaska GLOBEC program. His research interests include the effects of physical environmental variability on marine ecosystems.

Robert T. Cooney received his doctoral degree in Biological Oceanography from the University of Washington, Seattle (1971). He joined the faculty of the University Alaska Fairbanks and studied the plankton communities of Alaska waters for 30 years. His specialties include zooplankton assemblages found in coastal, shelf and oceanic waters of the northern Gulf of Alaska and Bering Sea. Dr. Cooney has had extensive experience with food-webs supporting juvenile pink salmon in Prince William Sound dating back to 1976. Collaborative investigations with the Prince William Sound Aquaculture Corporation and Alaska Department of Fish and Game were responsible for acquiring and using a real-time oceanographic buoy system in the Sound to log seasonal and annual changes in surface ocean climate and plankton. Most recently Dr. Cooney was the Lead Scientist for the EVOS-sponsored Sound Ecosystem Assessment (SEA) study of the post-spill recovery of pink salmon and herring. He is presently helping to revise the Gulf Ecosystem Monitoring program and implimentation studies.

Dr. Stan Rice-Stanley D. Rice has a Ph. D. in comparative physiology from Kent State University (1971). He has 30 years of experience in oil pollution work in Alaska; 15 years of program manager experience at the Auke Bay Lab; 12 years of experience on the *Exxon Valdez* spill. Short and long-term damages, and oil persistence are his primary research areas. Dr. Rice has over 100 peer-reviewed publications on oil effects. These publications include reviews and synthesis articles, covering effects of oil on fish, and specifically effects of oil on pink salmon. He has also contributed to the National Academy of Science reviews of oil inputs and effects. Dr. Rice has 25 papers on other contaminant issues as well.

Dr. Alan Springer has been involved in marine bird and mammal research in the N. Pacific for 25 years. In that time He has conducted studies at numerous breeding sites and at sea from southeastern Alaska to the Arctic Ocean, thereby gaining first hand knowledge of the haunts and habits of seabirds and marine mammals and an appreciation of the needs for and limitations of information on them. He also has broad experience in oceanographic studies and in research with lower trophic levels. As a peer reviewer during development of the APEX study, and as a core reviewer now, he is familiar with studies that have been supported by EVOSTC, as well as by others that are relevant to the goals of this synthyesis. Throughout his career, he has attempted to understand birds, mammals, fish, and plankton in the context of marine food webs and the physical environment. Dr. Springer has published several papers that synthesize large amounts on information on various aspects of the marine ecology of the N. Pacific

Dr. Philip Mundy-- Dr. Mundy has a Ph.D. from the University of Washington (1979). Dr. Mundy has 27 years of experience as a fisheries scientist, including 24 years in Alaskan fisheries research and management. His work included being a reviewer of fisheries research on the oil spill from 1989 until he joined the Trustee Council staff in 1999. Dr. Mundy currently is the Chief Scientist for the Gulf Ecosystem Monitoring and Science Coordinator, Exxon Valdez Oil Spill Trustee Council, Anchorage, AK.

Nearshore biologist--We will designate an experienced nearshore biologist for a more limited synthesis effort. This invitation will be based on needs identified by the contributing authors once existing work has been reviewed and as the subject matter is developed for the synthesis.

Literature Cited

Hare, S.R. and N.J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1997 and 1989. Prog. Oceanogr. 47, 103-145.

Peterson, C. 2001. The *Exxon Valdez* oil spill in Alaska: Acute, indirect and chronic effects on the ecosystem. Advances in Mar. Biol. 39, 1-103.

Scientific Support Services- Planning for EVOS Synthesis
Year 1, Cost Summary
Prepared by
Applied Marine Sciences, Inc.

FY 02

Task & Personnel	Total Hours	Rate	Cost	Total
SYNTHESIS				
Robert Spies	730	$119.31	$87.096.30	
Diane Stafford	51	$29.78	$1.518.78	
Sue Chase	44	$55.73	$2.452.12	
Deborah Florer	76	$42.41	$3.223.16	
Contract Writers	160	$100.00	$16.000.00	
Subtotal			##########	$110.290
Other Direct Costs				
Travel			9.875.00	
pping/Communications			1.500.00	
Miscellaneous			1.200.00	
Digital Graphics			4.000.00	
Total Direct Costs				**$16,575**
Total Labor and Direct				$126,865
Gen. and Admin. Overh	6.40%		$8.119.38	
Fee (5%)			$6,749.24	
TOTAL COST				**$141,735**

Scientific Support Services-Planning for EVOS Synthesis
Year 2, Cost Summary
Prepared by
Applied Marine Sciences, Inc.

Task & Personnel	Total Hours	Rate	Cost	Total
SYNTHESIS				
Robert Spies	730	$119.31	$87.096.30	
Diane Stafford	51	$29.78	$1.518.78	
Sue Chase	88	$55.73	$4.904.24	
Deborah Florer	76	$42.41	$3.223.16	
Nearshore Biologist	50	$100.00	$5.000.00	
Contract Writers	640	$100.00	$64.000.00	
Reviewers	25	$100.00	$2.500.00	
Subtotal			##########	$168.242
Other Direct Costs				
Travel			15.852.00	
pping/Communications			1.500.00	
Graphic Presentations			12.000.00	
Publication Costs			60.000.00	
Miscellaneous			1.200.00	
Total Direct Costs				**$90,552**
Total Labor and Direct				$258,794
Gen. and Admin. Overh	6.40%		$16.562.85	
Fee (5%)			$13,767.87	
TOTAL COST				**$289,126**

GEM Transition: Addressing Methodological Data Gaps, Submitted Under the BAA

Project Number:	02 601-BAA
Restoration Category:	Research
Proposer:	Prince William Sound Science Center Cordova, Alaska
Lead Trustee Agency:	NOAA
Cooperating Agencies:	
Alaska SeaLife Center:	
Duration:	1-year plus close-out
Cost FY 02:	$ 189,546.50 (includes agency overhead)
Cost FY 03 (Close Out):	$ 84,991.54 (includes agency overhead)
Geographic Area:	Prince William Sound and adjacent Gulf of Alaska
Injured Resource/Service:	Fishes and their Injured Consumers, Fisheries: Commercial, Recreational, and Subsistence

ABSTRACT

Recent research using natural stable isotope abundance (NSIA) has shown that the advective regime connecting the northern Gulf of Alaska (GOA) with Prince William Sound (PWS) may affect recruitment and nutritional processes in Fishes. PWS NSIA data has also been used to measure relative trophic level. The trophic levels of landed fish appear to undergo long-term systematic shifts. Accordingly, GEM will need to use NSIA to address study the effects of advective processes and anthropogenic trophic level effects on fishes and other ecosystem components as part of long-term monitoring studies. However, there are presently data gaps in the NSIA methodology that can be addressed expeditiously (within the next year) using GLOBEC and OSRI sampling platforms. This study will address specifically, (1) inter-species isotope effects among macro-zooplankton taxa and (2) develop non-lethal NSIA sampling for fishes.

INTRODUCTION

Recent research using natural stable isotope abundance (NSIA) has shown that the advective regime connecting the northern Gulf of Alaska (GOA) with Prince William Sound (PWS) may affect recruitment and nutritional processes in Fishes (Kline 1999a, 1999b). Stable isotope ratios of carbon and nitrogen have been shown to serve as effective tracers of energy supply in the PWS study area (Kline 1997, 1998, 1999a, 1999b) This is due to (1) the conservative transfer of carbon isotope ratios between the lower tropic levels (phytoplankton to zooplankton to forage fishes, etc.) of PWS and adjacent GOA waters up to the top consumers and (2) the naturally occurring gradient in $^{13}C/^{12}C$ productivity generated in the Gulf compared with the Sound. Organisms acquire these isotope ratios in response to the importance of the food in bulk body tissues. Isotope ratio analysis of tissues thus provide insight into both habitat usage and assist in quantifying amounts derived from various areas. PWS NSIA data can also be used to measure relative trophic level (Kline and Pauly 1998). Nitrogen isotope ratios provide excellent definition of relative trophic level. The heavy isotope of nitrogen is enriched by about 0.3 % with each trophic level and thus can accurately indicate the relative trophic status of species within an ecosystem (Minagawa and Wada 1984, Fry 1988) and is useful for food web model validation (Kline and Pauly 1998, Kline 2002).

Shifts in carbon flow occurring as a result in variations in the physical environment represent fundamental changes in the way the PWS ecosystem supports commercially important species. The availability of macrozooplankton forage for fishes varies in space and time because of changes in physical processes in PWS. The NSIA approach is unique in its ability to integrate time and spatial scales at mesoscale levels. No other technique currently available can generate such results. The natural tracer aspects of the approach emulates artificial tracer experiments without the burden of needing to generate signals or experimental artifacts. Tracking the effect of Gulf carbon inflow on pelagic production that appears to vary between years will thus be used to resolve the question of how oceanographic process affect fisheries recruitment in GEM.

NEED FOR THE PROJECT

A. Statement of Problem

The Problem: Long-term monitoring needs

As part GEM, there will be a need to assess effects of long-term ecosystem shifts, in particular, to get a better understanding of how these processes affect upper trophic levels. Decadal-scale changes in the production cycles of the subarctic Pacific Ocean have been conjectured to effect population changes in fishes and their zooplankton forage base (Brodeur and Ware 1992, Francis and Hare 1994). A "ring of zooplankton" occurring near the Gulf of Alaska (GOA) continental shelf break appears to undergo dramatic oscillations in abundance over decadal time scales (Brodeur and Ware 1992). This "ring of zooplankton" is driven onto the shelf providing the ecosystem with an important forage base (Cooney 1988, 1993). NSIA data suggested that the transport of zooplankton from the GOA into Prince William Sound (PWS) may provide significant quantities of forage for food webs and may be a good method for detecting changes in biophysical coupling in the PWS region (Kline 1999b, 2001).

B. Rationale/Link to Restoration

Because GEM will need to address the role advective processes as part of long-term monitoring studies NSIA will be a likely method. NSIA analysis could also be used to assess if trophic levels of landed fish undergo long-term systematic shifts (Pauly et al. 2001). There are, however, presently data gaps in the NSIA methodology that can be addressed expeditiously (within the next year) using GLOBEC and OSRI sampling platforms that would aid in GEM NSIA sampling design. Specifcally, prior and continuing analyses have focused on a narrow taxonomic range. In particular, plankton sampling was and is focused on *Neocalanus* copepods (Kline 1999b). Therefore a question, which is being addressed in the proposed project, arrises: How representative are *Neocalanus* of pelagic secondary production in terms of the (A) $^{13}C/^{12}C$ gradient between PWS and the GOA and (B) using $^{15}N/^{14}N$ to characterize relative trophic level in PWS and GOA pelagic systems? NSIA requires analysis of animal tissue. For mammals and bird taxa, hairs and feathers, respectively, can be used as tissue samples for NSIA and can also be collected non-lethally. Given that small samples (~ 1 mg dry weight) suffice for NSIA, a more conservation-minded approach should also be used when appropriate for fishes, e.g., those with slow growth. For example, rockfishes (*Sebastes* spp.), since they attain ages of ~ 100 years. Therefore a question, which is being addressed in the proposed project, is:(2) Can fish blood be used as a non-lethal sampling technique for NSIA of fishes and how useful would these samples be for (A) assessing the relative contribution of carbon sources using $^{13}C/^{12}C$ in relation to the gradient between PWS and the GOA and (B) using $^{15}N/^{14}N$ to characterize their relative trophic level in PWS and GOA?

Because of other on-going projects there are opportunties to address these issues through using planned cruises or analyzing samples on hand. Presently, samples are on hand of other taxa, euphausiids is particular, collected on SEA and GLOBEC cruises that have not been analyzed.

Euphausiids play a key role in the transfer of energy in marine food chains, forming an important dietary component for many consumers. Euphausiids of the sub-arctic Pacific consist of a complex of species in the genera *Euphausia* and *Thysanoessa*. Often euphausiids are studied collectively (e.g. Schell et al. 1998). However, $^{15}N/^{14}N$ data suggest there are significant differences in trophic level among euphausiid species and thus should be studied at the species level. Euphausiids appear to vary by as much as one trophic level covering a range corresponding to being primarily herbivorous (e.g., *Euphausia pacifica* at trophic level ~ 2; Kline unpublished data) to primarily carnivorous (e.g., *Thysanoessa longipes* at trophic level ~ 3) or about a 3 per mil $^{15}N/^{14}N$ range. Accordingly, the actual species of euphausiid consumed will determine the $^{15}N/^{14}N$ value of a consumer. Feeding on the more carnivorous of the euphausiids would effectively lengthen the food chain compared to feeding on a more herbivorous euphausiid. Food chain length is a key issue for GEM since food chain appears to be declining among fisheries (Pauly et al. 2001).

Because the chemical turnover rate of large fishes such as rockfishes is slow compared to juveniles and smaller species, small to meso-scale (e.g., sub-annual time scale) isotopic fluctuations in their muscle tissues are less likely. Instead, shifts are more likely to occur at annual time scales (Hesslein et al. 1993). Spatial isotopic variation among individual rockfish is likely to reflect their foraging range (Kline 1999b, Kline et al. 1998). The isotopic values of different animal tissues reflect their diet over temporal integrations of duration that are dependent upon tissue turnover rate (Hobson and Clark 1992). Previously, fishes were sacrificed in order to obtain muscle samples for isotopic and other (e.g., energetics) analyses (e.g. Kline 1999b). Whole blood turns over carbon isotopes only ~ 10% faster than muscle (Hobson and Clark 1992). Blood, however, can be separated into cellular and plasma fractions with the latter having a rapid stable isotope turnover rate with a half-life of a few days (Hobson and Clark 1993), and can be easily extracted non-lethally from modestly-sized anesthetized fish (Nielson and Johnson 1983). Blood and muscle tissue samples collected in 1999 pilot study confirmed this feasibility and yielded similar results. Comparative isotopic analyses were made of muscle and blood tissues from two pelagic rockfish species (dusky and black rockfishes, *Sebastes ciliatus* (N=7) and *S. melanops* (N = 1)) and two salmon species (coho and Chinook salmon, *Oncorhynchus kisutch* (N = 2) and *O. tschawytscha* (N = 1)) collected from Prince William Sound in 1999. A 3 mL blood sample was drawn from the hemal arch from each fish, split into two 1.5 mL centrifuge tubes, and centrifuged for 5 minutes to separate blood into cellular and plasma fractions. The plasma was decanted into additional 1.5 mL centrifuge tubes. Blood samples were then frozen, as were epaxial muscle tissue samples. One copper rockfish (*S. caurinus*) was sampled only for blood. It was anesthetized in MS222 and sampled, non-lethally, for blood. A 1.5 mL sample was drawn from its hemal arch. The copper rockfish was released live following an overnight recovery and observation period.

The muscle, plasma, and blood cells collected in 1999 had comparable isotope values. The plasma of pelagic rockfishes had elevated C/N ratios and depleted ^{13}C content indicative of increased lipid content. Following lipid normalization of the data, plasma was comparable to the isotopic content of other tissues. The copper rockfish, a demersal species, was ^{13}C enriched while the pelagic fishes were ^{13}C depleted. This observation is consistent with studies that showed that Gulf of Alaska pelagic carbon is ^{13}C depleted (Kline 1999b). The 1999 pilot study demonstrated the feasibility and further potential of sampling rockfishes for their blood as a means of non-lethal tissue sampling. Because of the small overall sample size of the 1999 samples, it is highly desirable to a generate a more robust sample base for GEM planning through additional sampling and analysis.

C. Location

Prince William Sound

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The participation of the community and incorporation of local knowledge into regional science efforts was the raison d'être for the PWSSC. The Center has a web page and distributes brochures and newsletters to all PWS communities. Our 1999 building addition includes an area where public presentations are given. Our education program provides a unique community involvement. To further our invovement in the entire community and external governing board was being implemented in 2000. The following are some of the individuals and groups that were invited to participate: President, Valdez Chamber of Commerce Valdez; Marine Safety Office Cmdr. US Coast Guard Valdez; Mayor, City of Whittier Whittier; President, Chugach Alaska Corporation Anchorage, SeaRiver; President, The Eyak Corporation Cordova; Alaska Dept. of Environmental Conservation, Valdez; U.S. Coast Guard Cmdr., Sweetbrier, Cordova; Herb and Barb Jensen, Cordova; Dave and Kim Erbey, Cordova Air Service, Cordova; Jim and Patty Kallander, Cordova; Sue Aspelund, Executive Director, Cordova District Fishermen United Cordova; Jack Babic, Jr., Cordova; Cal Baker, Cordova District Ranger, Cordova; Bob Baldwin. BP Exploration Shipping; Bob Berceli, Alaska Dept.& of Fish & Game, Cordova; Trish Berg, ARCO Alaska Shipping; Russ Bradley, President, Cordova Chamber of Commerce, Cordova; Pat Carney, BP Exploration Shipping; Dave Cobb, Mayor, City of Valdez, Valdez; Tom Colby, Alaska Tanker Company, Valdez; John Devens, Executive Director, PWS Regional Citizens' Advisory Council, Valdez, Gail Evanoff, President, Chenega Bay Village Council, Chenega Bay; Senator Georgianna Lincoln, State Senate, Alaska State Legislature, Juneau; Bob Henrichs, President, Native Village of Eyak, Cordova; David Janka, Auklet Charter Services, Cordova; Representative John Harris, House District 35, Alaska State Legislature, Juneau; Margy Johnson, Former Mayor, City of Cordova, Cordova; Tim Joyce, Alaska Dept. of Fish & Game, Cordova; Gary Kompkoff, President, Tatitlek Village Corporation Tatitlek; Carroll Kompkoff, President, The Tatitlek Corporation Cordova; Dune Lankard, Eyak Preservation Council, Cordova; Gerald McCune, President, Cordova District Fishermen United, Cordova; Jody McDowell, President, Prince William Sound Community College, Valdez; Vince Mitchell, SERVS Valdez; Riki Ott, Ph.D.. Copper River Watershed Project, Cordova; Brad Phillips, Phillips Cruises, Anchorage; Steve Ranney, Fishing and Flying, Cordova; Gayle Ranney, Fishing and Flying, Cordova; Ken Roemhildt, Superintendent, North Pacific Processors, Cordova; Jerry Sanger, Charter operator, Whittier; Dan Sharp, Alaska Dept. of Fish & Game, Valdez; Dorothy Shepard, Cordova Coordinator, PWS Community College, Cordova; Stan Stephens, Stan Stephens Charters, Valdez; Paul Swartzbart, Cordova; Chuck Totemoff, President, Chenega Bay Corporation, Anchorage; Bill Webber, Jr., Cordova; Mark Willette, Alaska Dept. of Fish & Game, Cordova; Ed Zeine, Mayor, City of Cordova, Cordova. Additionally, community involvement and traditional ecological knowledge were incorporated into the sampling.

PROJECT DESIGN

This study will address specifically, (1) inter-species isotope effects among macro-zooplankton taxa (with emphasis on euphausiids) and (2) develop non-lethal NSIA sampling for fishes based on using their blood.

A. Objectives

The questions listed below form the objectives of this project.

Euphausiids and other macro-zooplankton

1. Are there characteristic trophic levels for each of the major macro-zooplankton species, euphausiids in particular, as suggested by preliminary results (Kline 1999b)?

2. Conversely, are there temporal or spatial shifts in the trophic level of euphausiids and macro-zooplankton (by species)? (This might be the case since inter-annual differences in growth pattern have been observed, A.J. Paul, Univ. Alaska, Pers. Comm.).

3. Is there a euphausiid $^{13}C/^{12}C$ (carbon source) spatial pattern as seen for copepods (Fig. 3)?

4. Because euphausiids may live for up two years (K.O. Coyle, Univ. Alaska, Pers. Comm.), are those in the second year (larger individuals that will be distinguished from size distribution modes) different from first year euphausiids of the same species) in terms of carbon source or trophic level?

Blood as a non-lethal fish sample

The following questions address how similar samples of the plasma and cellular fractions of fish blood are to muscle samples.

5. Is it possible to use stable isotopes of blood to determine food source dependencies building upon previous results (e.g. Kline 1999b)?

6. Do muscle, blood cell and blood plasma tissues of individual fish have the same isotopic values (sub-objective: with and without normalization protocols outlined in Kline (1999b))?

7. Are the isotope-based food dependencies the same among fish species?

8. Are the isotope-based food dependencies the same among PWS sites for each rockfish species? {ANOVA will be used to simultaneously address site and species effects.}

9. Were shifts in either trophic level ($^{15}N/^{14}N$) or carbon source ($^{13}C/^{12}C$) discernable between samples taken in 1994-1995 (SEA project) compared to those from 2002 (this study)? (shifts in both C and N isotopes have been measured in Bering sea baleen whales leading to the conjecture that the system carrying capacity has declined (Schell 2000, 2001). Even a small sample in 2002 will aid in planning GEM NSIA sampling strategies.

B. Methods

Existing samples

The macro-zooplankton objectives of this project are based upon using an existing sample collection. More than 1500 euphausiids were collected during GLOBEC cruises (from 1997 to 1999; those from 2000 and 2001 are not yet inventoried) by the PI, but since analysis of these samples is not a GLOBEC goal, they remain unanalyzed. Copepods collected simultaneously with the euphausiid samples, however, are being analyzed as part of GLOBEC. (Copepods and pink salmon are the focus of the PI's GLOBEC project). The GOBEC-funded data will also be compared to euphausiid data, to test for with-in station and with-in area (adjacent stations) similarities and differences, see study questions 2 and 3.

Blood samples

Shipboard echo-sounders will be used to search for rockfishes and other demersals in suitable rocky high-relief habitat within the principal study areas: south Knight Island Passage (KIP) and Port Gravina (PG) in PWS. These two areas contain rocky high-relief habitat that is either continuous (virtually the entire area of south KIP) or discontinuous (heads of bays, islands and portions of the shoreline in PG). Rockfishes are known by the PI to exist in these areas. PG is accessible from Cordova (~2 boat-hours away) so that day trips are possible while working at KIP will require a live-abroad vessel (~6 boat-hours from Cordova). Once a specified site is established a mooring with a surface buoy will be deployed to facilitate re-locating the site. A sub-surface buoy will be left when the site is vacated at the end of a cruise to facilitate re-location in subsequent cruises.

The project will be run in conjunction with an OSRI-funded project that will be re-locating rockfish implanted with ultrasonic pingers (USP). USP rockfish will be located using a surface receiver (VEMCO VR60 and V10-10M directional microphone). Repeated surface observations of each USP rockfish will be used to ascertain the relative movements during an actual cruise. Once one or more fish are relocated within a reef area, dives will be planned around the predicted tides for underwater re-location or for capturing of fishes for blood/tissue samples.

In the OSRI project, individual USP rockfish will be located in situ (underwater) using a diver-held in situ receiver (VEMCO model number VUR 96) with Nitrox SCUBA. The latter will facilitate greater bottom time at expected depths (24 to 30m). During the 1999 study, dives were limited by tank size (8 and 10L scuba tanks) and tank content (air). In the proposed study we will use Nitrox breathing mixtures in 15L and double 15L tanks to maximize bottom time per dive. Increased bottom time will reduce the possibility of having to terminate the dive just as a USP rockfish is located (which is what happened during the 1999 study).

VEMCO has recently developed a diver-held receiver (VUR 96) for locating USPs underwater. Individual fishes can be tracked on the surface with a more sophisticated VR60 surface receiver (that has various capabilities, see VEMCO web page or catalog). The diver-held VUR 96 will be used to verify a living fish (as opposed to a lost USP on the bottom), to measure depth, to locate and document specific underwater location (e.g., crack in rock wall), and to locate fish underwater for recapture (e.g., to sample blood for isotopic analysis). During the 1999 study, we were able to verify that the USP that had not moved from the release site was indeed a living fish. The identification of this fish was unequivocal not only because of the USP signal, but also because of the specular reflections of our dive lights off the stainless steel surgical staples.

We will employ surface (rod and reel) and in situ capture of fish specimens. In situ capture enables selectivity for species (e.g., copper and quillback rockfishes) and size while minimizing handling trauma. During a pilot study in 1999 we employed varying in situ capture techniques and we attempted various technique modifications. We found we could most effectively collect rockfish nocturnally in situ using a hand net and during the day using hook and line from the research vessel (the latter technique lacked pre-capture selectivity). At night, it was possible to capture rockfish using a hand-net without quinaldine (anesthetic). Once netted, quinaldine was injected into the water near their gills to subdue the fish for transport to the surface. Barotrauma was minimized by slow diver ascent. A few rockfish, however, initially exhibited poor orientation but recovered to natural postures following an overnight period in a recovery tank (all captured fish are allowed to recover overnight prior to any experimental activity). Two attempts in 1999 to reduce barotrauma through air-bladder puncture were unsuccessful so this approach will not be attempted again. The PI discussed air-bladder puncture techniques with Scott Meyer (ADFG, Homer) and Rich Pyle (Bernice Bishop Museum, HI). Based on previous experience, these discussions, and the directed need to conserve rockfish from the collection permit process, air-bladder puncture will no longer be used. Surface capture using rod and reel was and will be used as alternative to in situ capture when time constraints do not allow for in situ capture. Barotrauma will be minimized by reeling fish in slowly.

Blood sampling from the hemal arch will follow protocols outlined by Nielson and Johnson (1983), ex-situ on a specially prepared table using 3 cc 18 gauge non-heparinized hypodermic syringes (to avoid sample contamination) on anesthetized (with MS 222) fish. Blood sample volume will be 1.5 mL since this amount of blood taken from a 20 cm long rockfish had no apparent ill-effects in 1999. For sacrificed fishes, one 3 mL blood volume will be sampled. 3 mL samples will be split and centrifuged immediately in 1.5 mL centrifuge tubes. Plasma will be decanted into separate centrifuge tubes for each 1.5 mL sample. Therefore, there will be two each cellular and plasma blood samples from sacrificed fish and one each for non-sacrificed fish. Epaxial muscle will also be taken when a fish is sacrificed. The two cellular and two plasma blood samples from sacrificed fish will be combined into single cellular and single plasma blood samples per fish following freeze-drying. Samples will be stored frozen (-20°C).

Samples will be freeze dried in a shelf freezer drier (designed for bulk samples) then ground to a fine powder in a dental amalgamator. Powdered samples will be stored in polyethelene LSC vials (22 mL) or centrifuge vials.

Sampling design

Euphausiids will consist of the four most common taxa: *Euphausia pacifica*, *Thysanoessa longipes*, *T. spinifera*, and *T. raschii*. 100 of each species will be analyzed /year, 80 of which will be first year euphausiids , the remaining 20/year will be those in their second year (which are rare in samples). Spatial-temporal differences in euphausiids will be addressed by having 40 be from the early season (May) and 40 late season (August) aggregated in groups of 10 according to station-area: 10 from PWS stations, 10 from shelf stations, 10 from shelf break stations and 10 from slope stations. The location of these stations on the "Seward Line" (on the continental shelf and further offshore, southeast of Seward) and PWS is available on the University of Alaska

GLOBEC web site. Note that not all taxa are found in some areas. The total number of samples to be analyzed in this study is 4 taxa by 100/year x 3 years (1997 to 1999) = 1200.

Fish sampling will be conducted at two sites, KIP and PG 9as above0. Up to 10 fish per species will be sacrificed for muscle-blood comparisons from each site. Additional samples of each species will be non-sacrificial, for blood only. Non-sacrificial fishes will be marked using fluorescent elastomer tags to avoid re-sampling within a cruise and to ascertain re-sampling between cruises. Taxa being targeted will be longer lived species, particularly demersals, especially *Sebastes* spp., however, all fishes of opportunity will be used to expand the breadth of the muscle vs. blood coverage. We are anticipating collecting 50 sacrificial samples at each location that will be sampled (twice) in 2002. Sampling will be dichotomized in to early (May to June) vs. late (July to August) season sampling because a large $^{13}C/^{12}C$ shift occurred between these times in 1995 (Kline 2001). Thus there will be 50 X 2 sites x 2 times or 200 sacrificial samples. Each sacrificial sample will consist of two blood tissues (blood cells and plasma) and one body tissue, epaxial muscle. Thus there will be 600 separate isotopic analyses for sacrificial samples. An estimated 50 non-sacrificial (blood-only) samples will be collected on each cruise (or 100 isotopic analyses per cruise). Therefore there will 200 non-sacrificial isotopic analyses for fishes for the year. Thus the fish isotopic analyses will total 800.

Isotope analysis

The rationale for, and detailed description of methods that will be used to generate the isotopic database for this study were described extensively in Kline (1999b) and so are only given briefly here. Samples will be analyzed in replicate and data averaged to provide one isotopic (per chemical element) datum per organism. Isotopic analyses will be performed at the University of Alaska Stable Isotope Facility using either a Europa Scientific 20/20 or Finnegan Delta Plus continuous flow isotope ratio mass spectrometer (CFIRMS). Organismal sub-samples or whole zooplankters, as appropriate for the mass requirements of the particular CFIRMS machine, will be weighed to the nearest 1 µg and loaded into combustion boats for mass spectrometric analysis.

Quality assurance and quality control protocols will include analyses of laboratory standards before and after every five samples as well as the sample duplication. Poorly replicated samples (difference in delta values $\geq$ 6 ‰) will be run again. A single isotopic analysis will generate the following data: $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios expressed in standard delta units, $\delta^{13}C$ and $\delta^{15}N$, respectively; and %C and %N. The delta notation used to express stable isotope ratios is reported as the per mil (‰) deviation relative to an international standard, air for nitrogen, and Vienna Peedee belemnite (VPDB) for carbon. By definition, the isotope standards have delta values of zero, i.e. $\delta^{15}N = 0$ ‰ for atmospheric N_2. Instrument replication is typically within 0.2 ‰. The %C and %N data will be used to calculate C/N atom ratios. The data will consist of mean $\delta^{13}C$, $\delta^{15}N$ and C/N of the replications. Nitrogen and carbon mass of euphausiids will be calculated by multiplying their freeze-dried weight by the %N and %C, respectively.

Stable carbon isotope ratios will be normalized for lipid content following the methods of McConnaughey and McRoy (1979) and expressed as $\delta^{13}C'$ following Kline (1999b). Whereas

$\delta^{13}C'$, $\delta^{13}C$ and $\delta^{15}N$ will be used in accordance to a particular data analysis context, "^{13}C" and "^{15}N" will be used to reflect respective generic $^{13}C/^{12}C$ and $^{15}N/^{14}N$ isotopic trends.

Trophic level will be determined by comparing $\delta^{15}N$ values to a reference value (Vander Zanden et al. 1997). The $\delta^{15}N$ of higher trophic levels will be calculated by adding the trophic enrichment factor, 3.4 (Minagawa and Wada 1984, Checkley and Miller 1989, Kline 1997), to the reference value. The herbivorous, i.e., trophic level = 2, copepod *Neocalanus cristatus*, in diapause will be used as the reference (Kline and Pauly 1998, Kline 1999b, 2001, 2002). Diapausing *N. cristatus* was chosen as the reference herbivore based upon observations that their carbon isotope values corresponded with those of PWS fishes (Kline 1999b). The following formula will be used to calculate trophic level: $TL_i = (\delta^{15}N_i - \delta^{15}N_H / 3.4) + 2$, where TL_i is the trophic level of organism i, $\delta^{15}N_i$ is the mean $\delta^{15}N$ value of organism i, and $\delta^{15}N_H$ is the mean reference herbivore $\delta^{15}N$ value.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

N/A

SCHEDULE

A. Measurable Project Tasks for FY02 (October 1, 2001 - September 30, 2002)

Oct. 01 - Jun. 02:	Preparation of archived samples (for Objectives 1 & 2) for mass spectrometry
May 02 - Aug 02:	Field sampling and prparation of fish isotope samples
Oct. 01 - Sep. 02:	Mass spectrometry at UAF (~ 6-9 month processing time)
Oct. 01 - Sep. 02:	Process isotope data

B. Project Milestones and Endpoints

Jun. 2002:	Preparation of archived samples for mass spectrometry completed
Aug. 2002:	Preparation of fish samples for mass spectrometry completed
Jan. 2002, 2003:	Attend Annual Restoration Workshop
Dec. 2002:	All data received from mass spec. lab.
Apr. 2003:	Isotope data processed
Apr. 2003:	Data integration and synthesis complete
Oct. 2002 - Sep. 2003:	Preparation for and dissemination of results at EVOS and other symposia
Jan. - Apr. 2003:	Preparation of reports
Apr. 15, 2003:	Draft final report
Sept. 30, 2003:	Final report

C. Completion Date

September 30, 2003 (Final Report)

PUBLICATIONS AND REPORTS

A paper will be produced but it is premature at this point to produce a title without the data. Note that the PI has a good publication record.

PROFESSIONAL CONFERENCES

Travel is requested for the PI to present results at a national (or when appropriate, international) meeting such as PICES, ASLO, or AGU and to attend workshops with collaborators. Travel to present project results at national meetings and to participate in collaborative workshops are essential to the project's success.

NORMAL AGENCY MANAGEMENT

N/A

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The PI is also a GLOBEC and OSRI PI and will be using these projects to augment the proposed and vice-verse. Collaboration with other EVOS investigators will continue. Results of analyses will be exchanged at workshops and by telecommunications. Sampling will be coordinated with other PI's (GLOBEC) and within the auspices of other biota sampling programs. Pertinent data of each sample (i.e. data on each individual sample will be shared among components).

PROPOSED PRINCIPAL INVESTIGATOR

Thomas C. Kline Jr., Ph.D., Prince William Sound Science Center
P. O. Box 705, Cordova, AK 99574
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PRINCIPAL INVESTIGATOR

T. Kline has been actively involved in stable isotope research since 1985. His has innovated applications of stable isotope analysis in fish ecology with emphasis on salmonid fishes in northern, western, south central and southeast Alaska. His techniques have enabled the quantification of the effect of salmon carcass nutrient input to juvenile sockeye salmon production. This research has been the first to provide direct evidence for the importance of salmon carcasses for juvenile salmon production (Kline et al. 1990). His stable isotope models also enable the quantification of different sources of production important in salmon ecosystems (Kline et al. 1993). Dr. Kline also led an investigation relating feeding strategies to growth forms in North Slope salmonids (Kline et al. 1998). His on-going efforts include collaborations with ADF&G, the North Slope Borough, and BPX. The results of these projects have been presented in numerous scientific papers as well as in public forums (speaking to local groups and classes). T. Kline initiated project \320I which has been the first comprehensive project using natural stable isotopes in Prince William Sound. Through this project he has developed new models and application of natural stable isotope abundance methods (Kline 1997, Kline and Pauly 1998). He was the first to provide direct evidence of the importance of carbon from the Gulf of Alaska in Prince William Sound (Kline 1997, 1998, 1999b). The study of the role of Gulf carbon in PWS was extended in a second EVOS project \311 which like \320I was completed in 1999. EVOS project 00541 was completed in 2001 while \393 will be completed at the end of FFY 2001.

OTHER KEY PERSONNEL

N/A

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2002 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Budget Category:	Authorized *FY 2001	Proposed FY 2002						
Personnel		$0.0						
Travel		$0.0						
Contractual	$0.0	$177,146.3						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$177,146.3	Estimated FY 2003					
General Administration	$0.0	$12,400.2						
Project Total	$0.0	$189,546.5	$84,991.54					
Full-time Equivalents (FTE)	0.0	0.7						
	*Dollar amounts are shown in thousands of dollars.							
Other Resources								

FY02

Project Number: 02601-BAA
Project Title: GEM Transition: Addressing Methodological Data Gaps, Submiited Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2002 EXXON VALDEZ TRU: COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Budget Category:	Authorized *'FY 2000	Proposed FY 2001						
Personnel	$0.0	$53,577.5						
Travel	$0.0	$4,948.0						
Contractual	$0.0	$74,700.0						
Commodities	$0.0	$5,800.0						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$139,025.5	Estimated FY 2002					
Indirect	$0.0	$38,120.8						
Project Total	$0.0	$177,146.3	$79,061.9					
Full-time Equivalents (FTE)	0.0	0.7						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

Project Number: 02___
Project Title: GEM Transition: Addressing Methodological Data Gaps, Submiited Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FY02

FORM 4A
Non-Trustee

2002 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FY 2000
T. Kline	Principal Investigator		3.0	10230.0		30,690.0
TBN	Technician, Lab		5.0	4577.5		22,887.5
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	8.0	14807.5	0.0	
					Personnel Total	$53,577.5

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
PICES meeting*	1200.0	1	8	110.0	2,080.0
registration and car rental	300.0	1	8	55.0	740.0
EVOS and collaborative workshops	300.0	2	8	141.0	1,728.0
car rental	0.0	0	8	50.0	400.0
*North Pacific Marine Science Organization					0.0
Victoria, B.C					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$4,948.0

FY02

Project Number: 02___
Project Title: GEM Transition: Addressing Methodological Data Gaps, Submiited Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 4B
Personnel
& Travel
DETAIL

2002 EXXON VALDEZ TRU! COUNCIL PROJECT BUDGET
October 1, 200ı - September 30, 2002

Contractual Costs:				Proposed
Description		cost per unit		FY 2000
PWSSC network charge by computer-months	computer months	8	100	800.0
Stable Isotope Analysis	number:	2000	25	50,000.0
freeze drier charge	number:	2000	3	6,000.0
photocopying				600.0
shipping				300.0
communications (fax and phone)				1,000.0
page charges				0.0
PWSSC WWW support				1,000.0
vessel charter (half-cost as OSRI will fund an additional 15 days)		1000	15	15,000.0
			Contractual Total	$74,700.0

Commodities Costs:	Proposed
Description	FY 2000
Lab supplies miscl	2,000.0
Lab supplies: chemicals, vials, knives	2,000.0
Office supplies miscl	500.0
Computer supplies and upgrades	1,000.0
Dyesub, photog. (presentation materials)	300.0
Commodities Total	$5,800.0

FY02

Project Number: 02___
Project Title: GEM Transition: Addressing Methodological Data Gaps, Submiited Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 4B
Contractual &
Commodities
DETAIL

2002 EXXON VALDEZ TRU: , COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2000
			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: Description	Number of Units	
Computer, MAC G4	1	

FY02

Project Number: 02___
Project Title: GEM Transition: Addressing Methodological Data Gaps, Submiited Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 4B
Equipment
DETAIL

Implementation of an Ocean Circulation Model: A transition from SEA (PWS) to GEM (GOA)

Project Number:	02603
Restoration Category:	Research
Proposer:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cooperating Agencies:	
Alaska Sea Life Center:	No
Duration:	1-year project
Cost FY 02:	$68,504
Geographic Area:	GOA including PWS and Cook Inlet
Injured Resource/Service:	

ABSTRACT

During this transition year (FY02), we propose to establish a 3-D ocean circulation model in the Gulf of Alaska (GOA) to lay down a foundation for GEM starting in 2003 in order to couple this model to a hydrological model and a biological model. This model will cover the entire GOA, including PWS and Cook Inlet. The horizontal resolution of this model is 4'x2' minutes (about 3.7km at 6o^{o} N). This model will be forced by tides, the Alaska Current inflow/outflow, freshwater discharge, and wind stress derived from NCEP (National Center for Environmental Prediction).

INTRODUCTION

In the SEA program, extensive observations of phytoplankton and zooplankton, as well as oceanography, have been made during 1995–1998 (Cooney, 1996, 1997; McRoy et al. 1997; Thomas et al. 1997). Fish larvae and schools of some kinds were also measured (Stokesbury et al. 1997). The 3-D ocean circulation model explains some mechanisms with a application to biology (Mooers and Wang 1998; Wang et al. 2001). For example, the oceanic advection and diffusion only can explain the existing phytoplankton and zooplankton movement, while the spring blooms and sometime the later summer blooms (i.e., second bloom in the year) due to the ecosystem dynamics cannot be explained by a physical only model.

Based the observed data collected from 1995–1998 in PWS and the forcing of tide, coastal current inflow/outflow, freshwater discharge, and wind stress, a 3-D PWS model developed from the SEA Project (Wang and Ikeda 1996; Mooers and Wang 1998; Wang et al. 1999, 2001) has been used to produce a continuous 4-year, 3-D fields of velocity, and temperature, salinity. In addition, the interannual variability of PWS ocean circulation, temperature and salinity due to interannually variable atmospheric forcing has been studied. Thus, we can identify the key environmental parameters in a long-term monitoring program (such as GEM) to assist resource managers through sensitivity studies. During 1998-2000 (SEA Project 00398), the substantial progress has been made for the PWS ocean circulation modeling:

1. We provided 3-D velocity fields to A. Brown for her research (Brown et al. 1999), because she found that physical forcing from the 3-D model fits well with her biological data. Thus, she strongly urges us to provide four consecutive years (1995–1998) of the 3-D current velocity, temperature and salinity for her continuous proposal to EVOS.

2. We have collected the wind data from 1995-1998 at mid Sound station (see Fig. 1) and other stations (not shown) with the efforts of Dr. Vince Patrick, Jenny Allen, and Stephen Bodnar (the first-year subcontract). These data have a 30min interval, which were averaged to hourly or 3-hourly interval to drive the model.

3. The year-to-year variability of the circulation due to wind forcing has been examined (Figs. 2-4).

4. We are preparing a manuscript on the sensitivity studies of PWS circulation with respect to the forcing functions: winds, freshwater runoff, ACC inflow/outflow, and tide (Jin and Wang 2001).

NEED FOR THE PROJECT

A. Statement of Problem

Since SEA project started more than five-year ago, physical oceanographers and modelers at IARC and IMS/UAF have developed a PWS circulation model (Wang et al. 2001) and a coupled biological-physical model (Jin et al. 2001). Because the PWS model has a limited region with two open boundaries, physical conditions are required to prescribe these boundary conditions into the model. This drawback was noticed during the course of the research. To overcome this drawback and to face the challenge of the GEM goals, we propose to develop a GEM-based 3D circulation model (Fig. 1), covering the entire GOA including PWS and Cook Inlet. This model has a potential for future coupling with

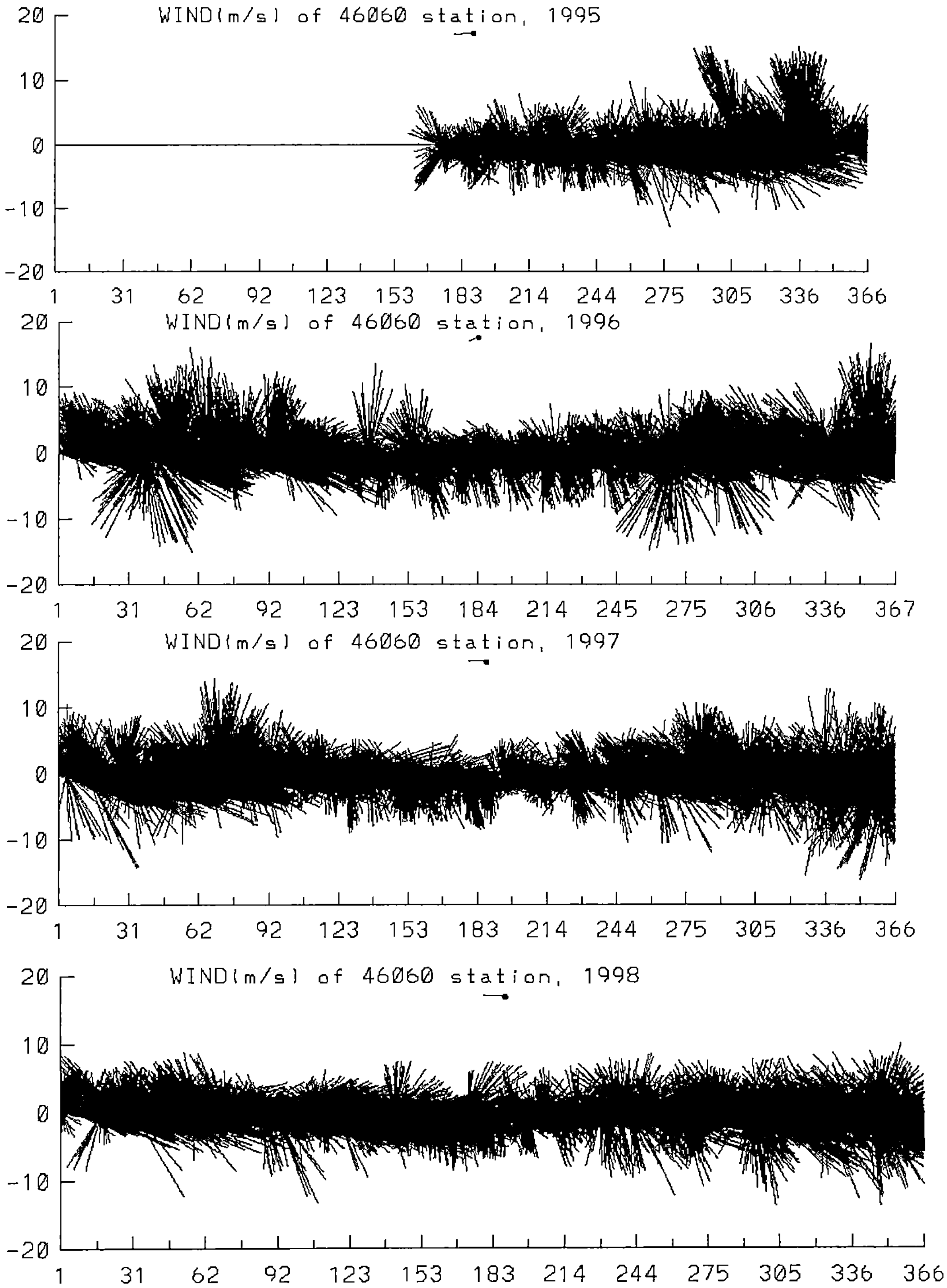

Fig 1. Wind vector at the mid-sound of PWS from 1995–1998.

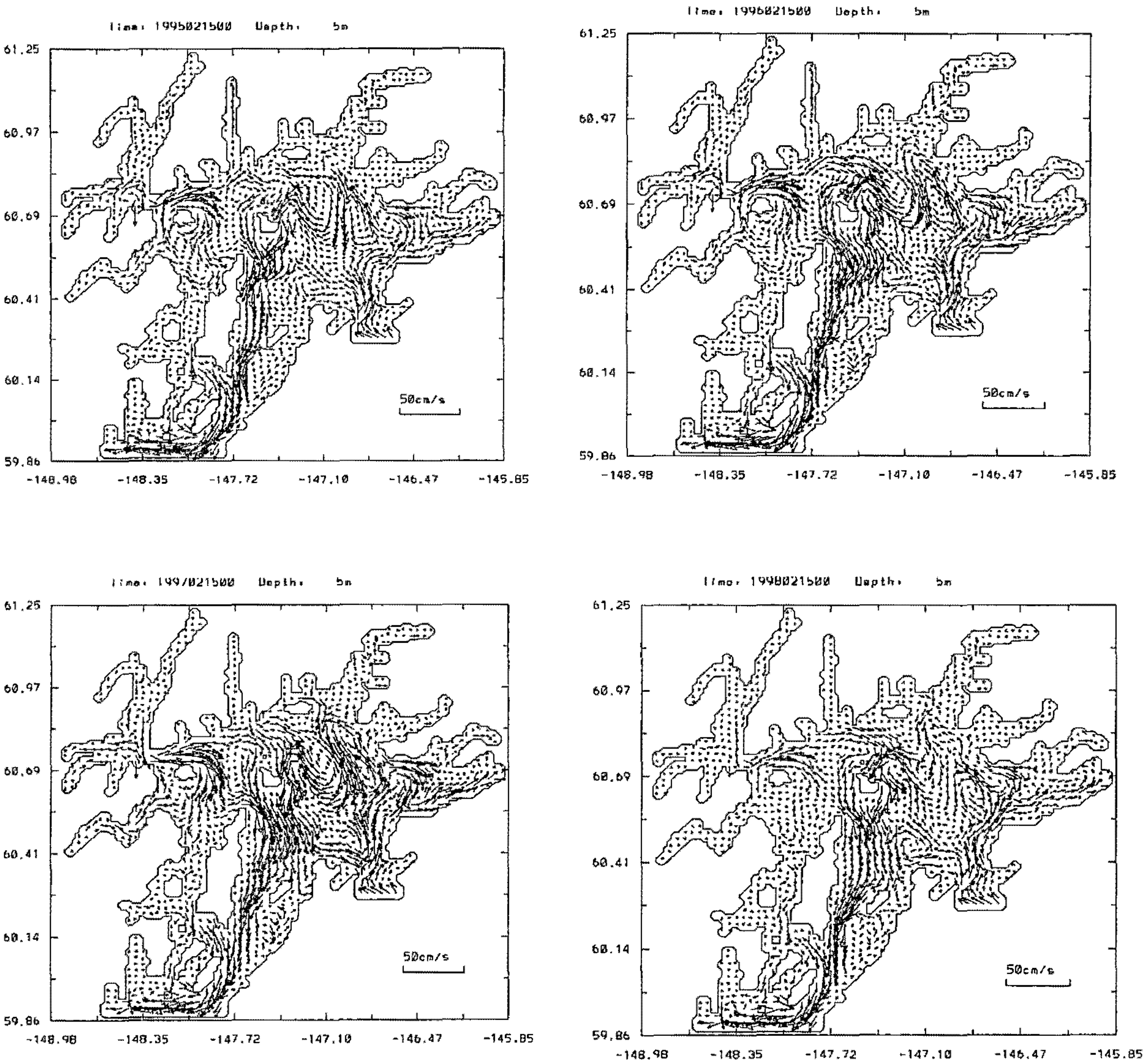

Fig. 2. Surface current of February 15 of 1995-1998.

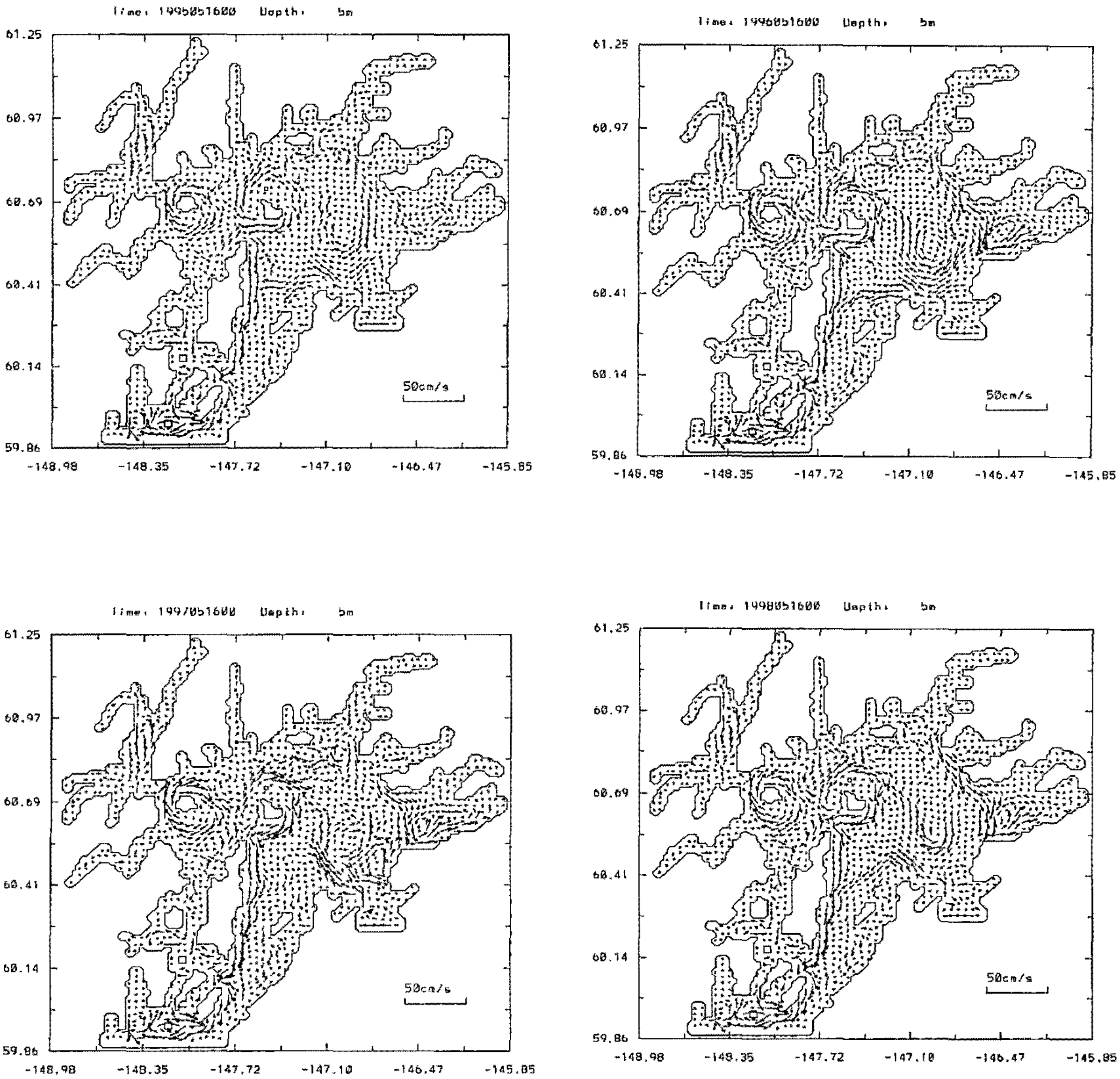

Fig. 3. Surface current of May 15 of 1995-1998.

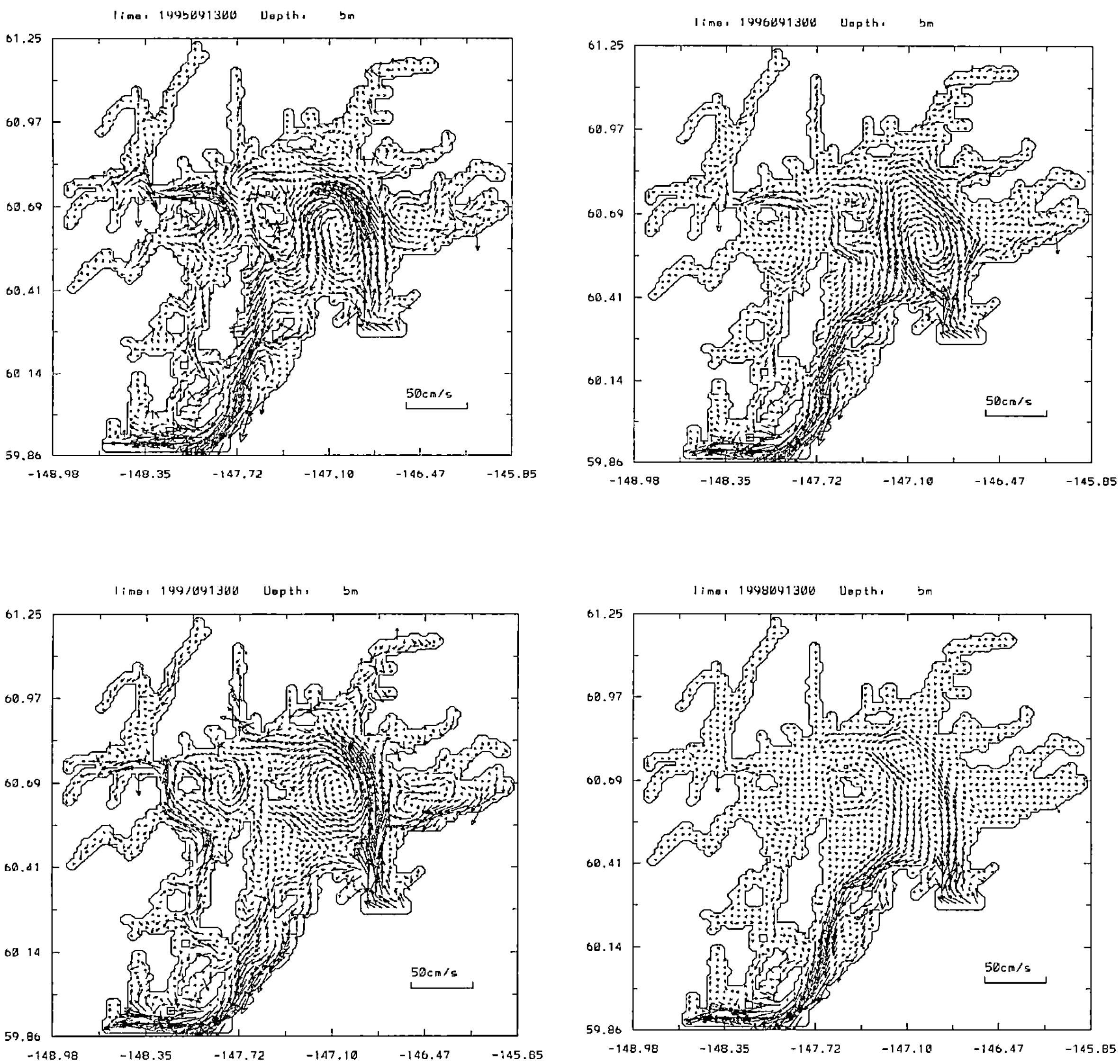

Fig. 4. Surface current of September 15 of 1995-1998.

1. Hydrological model to calculate freshwater runoff of the point source (rivers) and line source, because the line source was at least comparable to the point source.

2. Biological model with nutrients, phytoplankton, zooplankton, and detritus, which describe the primary and second productivity in the region.

3. Developing a nowcast/forecast system (Wang 1999, 2001) to provide prediction of the ocean states to users, such as environmental policy makers, managers, and fishing fleets, with sophisticated data assimilation of satellite-sensed sea surface height (SSH), SST, biological variables, surface current, as well as in situ oceanographic dataset of any type.

Therefore, it is essential to establish a 3D, high-resolution ocean circulation model at the very beginning of GEM to provide necessary physical setting/forcing/information to biological and other disciplines. This model also can provide boundary conditions to the PWS model.

B. Rationale/Link to Restoration

The Gulf of Alaska (GOA) including PWS and Cook Inlet is located in the northestern Pacific. A systematic numerical simulation (study) of the physical oceanography and ecosystem in the region is essential and timely to understand the physical-biological system in order to provide scientific knowledge and information to the state government, local community, etc. Because of its rich resources in sea birds, mammals, salmon, forage fish, and many other animals,

Possibly because the North America's largest oil spill by T/V Exxon Valdez on March 24 1989 in PWS seriously damaged the ecosystem in PWS and the adjacent downstream waters in GOA, such as Cook Inlet and Kachemak Bay, extensive observational programs have been carried out in PWS and GOA. The SEA (Sound Ecosystem Assessment) project was a major effort since. This interdisciplinary project started in 1994 with major focus on pink salmon, Pacific herring habitat, ecology, and physical oceanography. As the physical component, the effort was placed on field program and numerical modeling.

After the implementation of 3D-PWS model and a passive tracer simulation were accomplished (Mooers and Wang 1998; Deleersnijder et al 1998), a seasonal simulation (12 consecutive months) has been followed up by Wang et al. (2001) using the SEA observations of 1996 only. However, the field observations in physical and biological oceanography from 1995–1998 during the SEA program have not fully validated. In addition, the interannual variability as observed can not be explained by PWS model only, unless a large region is included. Thus, after the SEA has been synthesized (SEA Synthesis Volume, 2001), it is necessary to step up to develop a large-scale, 3D, high-resolution ocean circulation model (http://www.frontier.iarc.uaf.edu:8080/~jwang) for the GEM research themes (http://www.oilspill.state.ak.us/future/gem.html), such as coupled biological-physical modeling, coupled hydrological-physical modeling, and towards a nowcast/forecast system for GOA (Wang 2001).

The simulated results will be valuable to assist resources managers to forecast pink salmon and Pacific herring abundance and to anticipate or understand changes in the ecosystem. In addition, key elements will be identified that will be pertinent to include in a long-term monitoring program, leading to an establishment of a nowcast/forecast system in GOA using this 3D-GOA model.

C. Location

The research is conducted for the ecosystem of GOA (Fig. 1) that will help understanding the basic physical environment and forcing to the biological research community and resource managers.

COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

Not only the research institutions (such as IMS and IARC of UAF), but also the local community (Regional citizens' Advisory Council, RCAC, at Cordova and Cook Inlet) will be involved. They are concerned with possible long-term oil spill impact on the ecosystem and local community as well.

PROJECT DESIGN

A. Objectives

1. Implement a 3D-GOA model to simulate ocean circulation, T, S, vertically mixing coefficients using 2.5 turbulence closure model. The model validation will be conducted using actual observations in the future.

2. Provide biologists and resource managers the 3-D fields (longitude, latitude, and depth) of velocity, T, S, etc. of the ocean states.

3. Put the simulation results in a new server at IMS-IARC/UAF to enhance the information exchange and scientific communication with Alaskan citizens and local community.

B. Methods

The above objectives will be accomplished using a 3D-GOA ocean circulation model (Fig. 5).

1. Forcing data

    i. Winds: The daily wind speeds and directions will be obtained from NCEP reanalysis, available from 1957-2000 (we need to purchase the data.)

    ii. Tides: Oceanic tidal harmonic constants for 6 major tides (M_2, S_2, S_2 K_1, P_1, O_1) will be specified in the southern boundary (Schwilerski 1980).

    iii. Freshwater runoff: The hydrological model for freshwater discharge into GOA will be implemented in year 2003 (GEM project) to provide runoff discharge. At the present time, the surface temperature and salinity will be restored to the NODC (National Oceanographic Data Center) Levitus T and S dataset.

    iv. Daily heat flux for the same period will be extracted from the NCEP reanalysis.

    v. The monthly inflow/outflow of Alaska Current and Alaska Stream will be fixed to the observations of Onishi and Ohtani (1999).

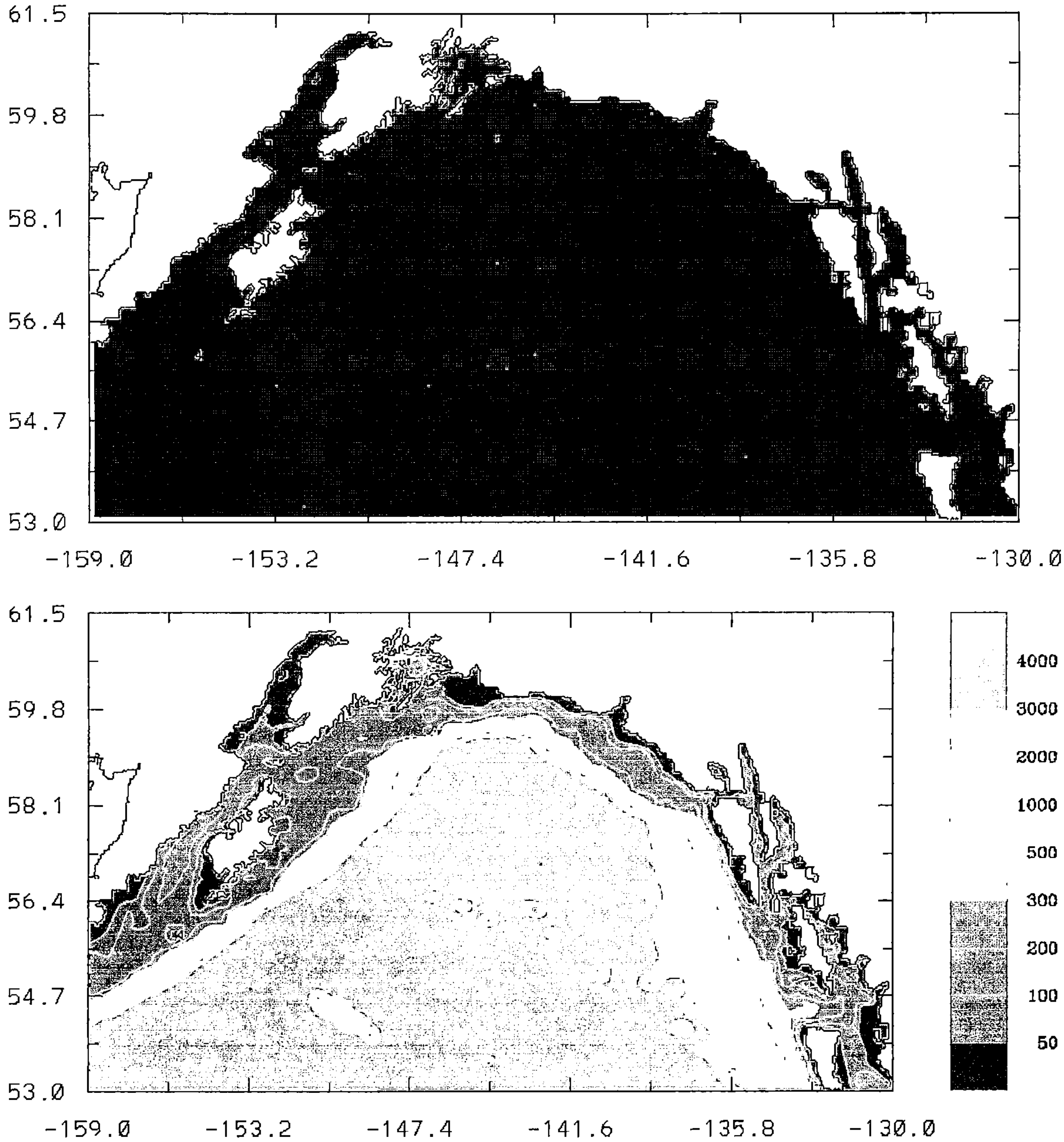

Fig. 5. Proposed 3D-GOA ocean circulation model for GEM: (upper) model grids and (bottom) topography).

2. Model simulations

The model resolution is about 3.75km and time stepping is 5mins/10secs for the internal/external mode. There are 20 levels in the vertical with 8 levels in the upper 50 meters to resolve the upper mixed layer. The purpose of this setting is to resolve the biological onset of the blooms in the upper mixed layer. Thus, the ocean model setting is suitable for the future biological model coupling.

Figure 6 shows the model run only under forcing of tides of six constituents. The model shows very strong tidal current in Cook Inlet, but weak tidal current in PWS, consistent with the observed information and previous tidal simulation in PWS (Wang et al 1997).

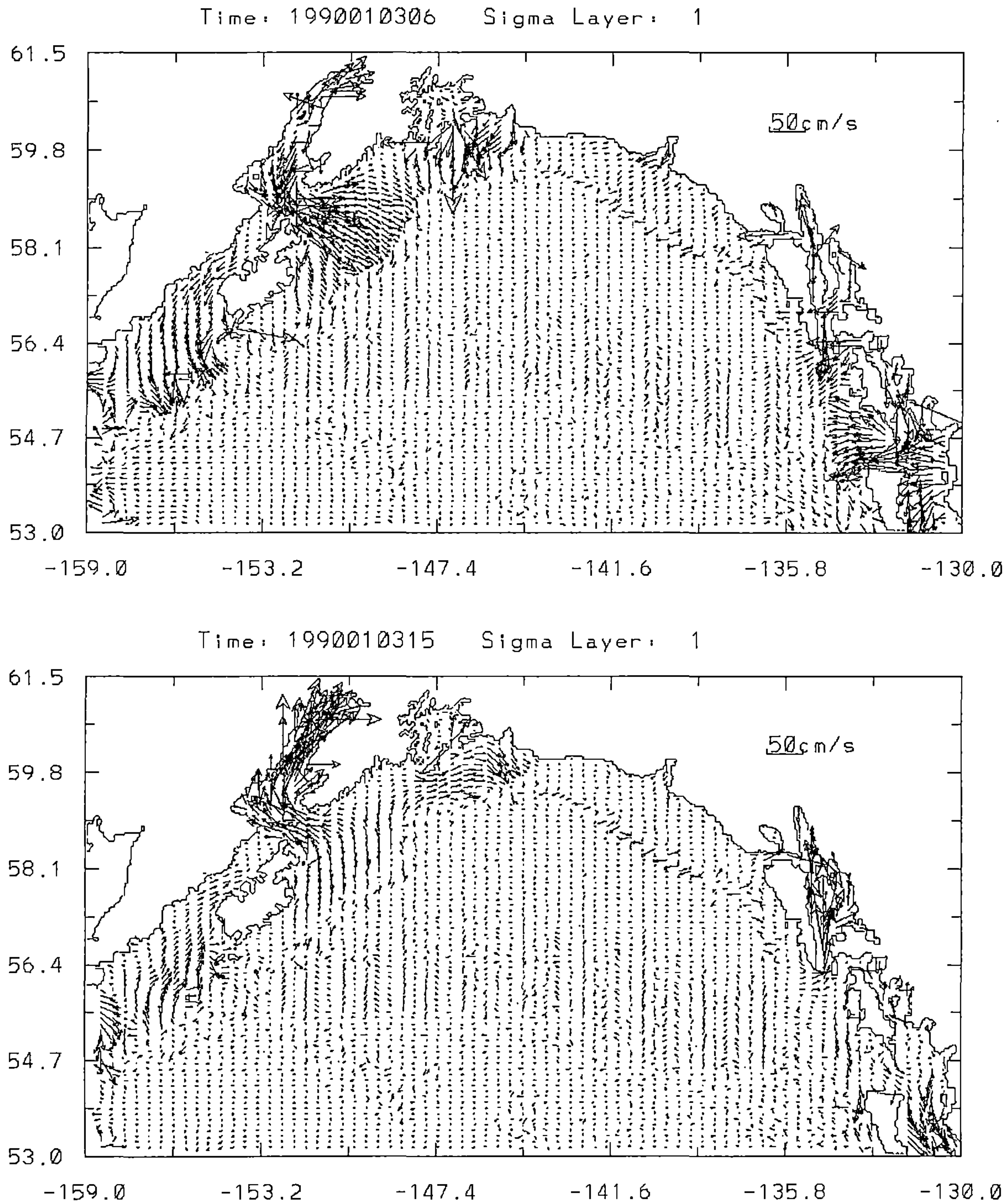

Fig. 6. Surface current at 6h (ebb) and 15h (flood) on 01/03/1990

A annual cycle (12-month) simulation will be conducted under the climatological (44-year mean) forcing described above (wind, heat flux, inflow/outflow with restoring to surface T and S) and tidal forcing. The outputs will be validated based on observations at coastal tide gauges, moorings, and CTD transects, etc.). Then, the model outputs (velocity, T, S, mixing coefficients, etc.) in 3D grids will be provided to biologists who need these outputs to verify their phytoplankton and zooplankton data. The monthly climatology for above mentioned variables will be produced.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

The data preparation will be conducted by Dr. Jin and a M.Sc. student (Yongmei Qin). The PI got funded from OSRI (Oil Spill Recovery Institute) for one-year (2000-2001) term (50K) of the proposal entitled "A 3-D coupled biological-physical model for the ecosystem in PWS, Alaska" to support 6-months of salary for Dr. Jin. This project will benefit the present proposed research by paying half of the time for Dr. Jin to focus on the intensive modeling work and data analyses.

SCHEDULE

A. Measurable Project Tasks for FY 02 (October 1, 2001 – September 30, 2002)

December 31:	Complete tide simulation and preparation of the NCEP climatological forcing
January 18–28 (3 of these days):	Attend Annual Restoration Workshop (Wang, Jin, maybe student as well)
March 31:	Start to implement the forcing data to the 3D-GOA model
August 31:	Complete the modelling of the seasonal cycle
September 15:	Put the simulation to the webside

B. Completion Date

September 30, 2002

PUBLICATIONS AND REPORTS

Manuscript (entitled "Tidal current and tidal residual current in GOA" will be prepared and submitted to a refereed journal for formal publication. I may present the results and publish another paper in the book entitled "Computer Modeling of Seas and Coastal Regions, V, 2002" in which I serve as a member of the International Advisory Committee for three years now.

PROFESSIONAL CONFERENCES

The PI and Dr. Jin plan to attend the annual EVOS meeting, 2002 Ocean Science Meeting in Hawaii, presenting the updated research results. This is an excellent way to communicate with our colleagues and to get recognised in the ocean science community. We also encourage the student (research assistant) to attend the scientific meeting and EVOS workshop.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This proposed research will be co-ordinated with 1) E. Brown's project (if her proposal gets funded) by providing her with the model outputs; 2) B. Norcross's proposal for EVOS by providing our 3-D model outputs, and other potential proposals for the restoration effort for GEM. We are willing to provide our simulation outputs to all EVOS-funded proposals by putting our simulation results on our website in both digital and graphic formats.

PROPOSED PRINCIPAL INVESTIGATOR

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University of Alaska Fairbanks
P.O. Box 757335
Fairbanks, Alaska 99775-7335
907-474-2685
907-474-2643
jwang@iarc.uaf.edu

PRINCIPAL INVESTIGATOR

Dr. Jia Wang, the PI, will be involved in the entire course of the project, providing scientific guidance to the project, without claiming salary. The PI needs one graduate student to conduct forcing data from NCEP reanalysis.

OTHER KEY PERSONNEL

Dr. Meibing Jin, who is currently working on this EVOS-funded project awarded to the PI (Wang), will continue conducting the simulation, and will partially supported by the OSRI fund for six months, plus UAF overhead (25%), benefit, and travel to scientific conferences/workshops.

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2002 *EXXON VALDEZ* TRU : COUNCIL PROJECT BUDGET
October 1, 20L . .eptember 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$0.0						
Travel		$0.0						
Contractual		$68.5						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$68.5	Estimated FY 2003					
General Administration		$4.7						
Project Total		$73.2						
Full-time Equivalents (FTE)		1.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY02

Prepared:

Project Number: 02603
Project Title: Implementation of an Ocean Circulation Model: A transition from SEA (PWS) to GEM (GOA)
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2002 *EXXON VALDEZ* TRU COUNCIL PROJECT BUDGET
October 1, 200 - September 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$45.7						
Travel		$7.5						
Contractual		$0.0						
Commodities		$1.6						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$54.8	Estimated FY 2003					
Indirect		$13.7						
Project Total		$68.5						
Full-time Equivalents (FTE)		1.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

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

Student personnel costs include non-resident tuition of $6,048 per year.

FY02

Prepared:

Project Number: 02603
Project Title: Implementation of an Ocean Circulation Model: A transition from SEA (PWS) to GEM (GOA)
Name: Jia Wang

FORM 4A
Non-Trustee
SUMMARY

2002 *EXXON VALDEZ* TRU: COUNCIL PROJECT BUDGET
October 1, 200ı - ‿eptember 30, 2002

Personnel Costs:				Months	Monthly		Proposed
	Name	Position Description		Budgeted	Costs	Overtime	FY 2002
	Wang, J.	PI		0.0	0.0		0.0
	Jin, M.	Research Assistant Professor		6.0	4.9		29.2
	TBA	M.S. Student		9.3	1.8		16.5
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		15.3	6.7	0.0	
						Personnel Total	$45.7

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 2002
	Fairbanks to Anchorage (workshop)	500.0	3	9	129.0	2.7
	Fairbanks to Hawaii (Ocean Science meeting)	700.0	3	21	129.0	4.8
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$7.5

FY02

Prepared:

Project Number: 02603
Project Title: Implementation of an Ocean Circulation Model: A transition from SEA (PWS) to GEM (GOA)
Name: Jia Wang

FORM 4B
Personnel
& Travel
DETAIL

2002 *EXXON VALDEZ* TRU : COUNCIL PROJECT BUDGET
October 1, 200 - September 30, 2002

Contractual Costs:	Proposed
Description	FY 2002
Contractual Total	$0.0

Commodities Costs:	Proposed
Description	FY 2002
Project supplies	0.9
Data purchase	0.7
Commodities Total	$1.6

FY02

Prepared:

Project Number: 02603
Project Title: Implementation of an Ocean Circulation Model: A transition from SEA (PWS) to GEM (GOA)
Name: Jia Wang

FORM 4B
Contractual &
Commodities
DETAIL

2002 *EXXON VALDEZ* TRU[illegible] COUNCIL PROJECT BUDGET
October 1, 20[illegible] - [illegible]eptember 30, 2002

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2002
			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: Description	Number of Units	

FY02

Prepared:

Project Number: 02603
Project Title: Implementation of an Ocean Circulation Model: A transition from SEA (PWS) to GEM (GOA)
Name: Jia Wang

FORM 4B
Equipment
DETAIL

02604

EXXON VALDEZ **Oil Spill Trustee Council**
FY 02 Detailed Project Description

Gear Selectivity in Trawl Surveys along the Northern Gulf of Alaska

Project Number:	02604
Restoration Category:	Monitoring
Proposer:	ADF&G
Lead Trustee Agency:	ADF&G
Cooperating Agencies:	USGS (BRD)
Alaska SeaLife Center:	No
Duration:	1-year project
Cost FY 2002:	$ 52.1 K
Cost FY 2003:	$ 15.0 K
Cost FY 2004:	$ 0.0 K
Geographic Area:	Lower Cook Inlet
Injured Resource/Service:	Forage Species/Commercial Fishing

ABSTRACT

This project will explore approaches to developing long-term monitoring techniques for forage fish populations in Cook Inlet, an area representative of ecosystem conditions and changes in the northern Gulf of Alaska. Time series data are available for two different trawl surveys conducted in Kachemak Bay in lower Cook Inlet. One survey series dates to the 1970s and uses a small-mesh trawl that catches species representative of the underlying forage base in this area. The second survey series, dating to 1990, uses a larger-mesh trawl fished closer to the bottom and catching a substantially different speies composition. Comparison of the catch composition time series from these two survey types will allow determination of gear selectivity between these trawls. Gear selectivity and correlation of catch rates among different gears and different surveys will improve the utility of other trawl data sets withing the northern Gulf of Alaka. Gear selectivity information will also be important to the development of a long-term program for ecosystem monitoring along the northern Gulf of Alaska.

INTRODUCTION

The ecosystem structure in the nothern Gulf of Alaska, as indicated by the dominant fish and predator populations, exhibited a significant shift in the late 1970s and early 1980s, likely triggered by a decadal shift in climate (Figure 1; Piatt and Anderson 1996; Bechtol 1997; Anderson et al. 1997). Common murres, black-legged kittiwakes, harbor seals, and Steller sea lions are examples of apex predators, consumers at or near the top of the marine food chain. Abundances of these and other apex populations have declined in the Gulf of Alaska since the 1970s. At the same time, the gulf has undergone a drastic change in the type and abundance of forage species, such as herring, capelin, sand lance, shrimp, pollock and cod (Bechtol 1997). Warming waters likely resulted in a shift from a forage population dominated by shrimp to a population dominated by fish, particularly gadid species such as pollock and cod. Small-mesh trawl surveys, conducted in Kachemak Bay in lower Cook Inlet since 1971, have produced a strong database to document these changes (Figure 1). A large-mesh trawl survey conducted in this same area since 1990 reveals similar natural resource abundance trends, although the species composition of these two surveys differs somewhat due to gear selectivity pattern. Together, these two surveys provide a more comprehensive picture of the underlying nearshore ecosystem along the northern Gulf of Alaska than can be provided by a single biased gear type. Coupling trawl survey data with information on apex populations will allow scientists to identify ecosystem links with the ultimate goal to improve: (1) monitoring of ecosystem changes; (2) identification of species or resources that are at risk; and (3) management of human use to reduce impacts on species at risk. At least five presentations and manuscripts have already resulted from related projects during FY96-99.

NEED FOR THE PROJECT

A. Statement of Problem

Fish, seabird, and marine mammal resources and services were injured by the 1989 *Exxon Valdez* oil spill. The oil spill also followed, and possibly exacerbated, a massive shift in ecosystem structure, likely related to a shift in climate and water temperatures. Concurrent with these changes, human use of natural resources has intensified in the oil spill area. Over half of the state's permanent residents live within the geographic area of the northern Gulf of Alaska and most of the state's one million tourists visit this region annually. Alaska's private sector economy depends heavily on natural resources in this region, and increasing tourism and recreational use, as well as increased commercial and sport fishing pressure, are all human activities that could affect the marine resources and ecosystem of the northern Gulf of Alaska. Human use demands for natural resources, particularly in the Cook Inlet area, can be expected to continue to increase in the future. In order to manage for optimum patterns and levels of human use, it is important to understand how ecosystem links are restructured following major perturbations, particularly how ecosystem productivity is influenced by natural changes and human activities. Critical to this understanding is long-term monitoring of a wide variety of ecosystem parameters and evaluation links among those parameters.

Standardized small-mesh trawl surveys have been conducted by the Alaska Department of Fish and Game in Kachemak Bay area since 1971. These surveys were conducted from one to three times annually as a means of assessing pink shrimp populations (*Pandalus borealis*). However, the commercial fishery has remained closed since 1986 due to a collapse of the shrimp population, and it cannot be determined when, if ever, this fishery will be reopened. Given the shrimp decline, compounded by a declining department operating budget amid increasing demands for assessment and management of other resources, the Kachemak Bay small-mesh trawl survey was reduced to a biennial and then a triennial survey frequency. To better assess Tanner crab, a species actively targeted by both recreational and subsistence user groups, ADF&G has also conducted an annual bottom trawl survey with the larger-meshed, 400-Eastern bottom trawl since 1990 (Bechtol 2001). ADF&G recognizes the utility of both surveys as tools to monitor components of the northern Gulf of Alaska ecosystem, particularly if links can be established among ecosystem components in ways that allow a priori estimation of ecosystem changes. A biometric analysis is needed to determine relative catchabilities of these two bottom trawl designs (Sissenwine and Bowman 1978; Walsh 1992; Dickson 1993). This analysis will facilitatae the development of future GEM research and monitoring programs to provide the data for long-term monitoring of ecosystem health in the northern Gulf of Alaska.

B. Rationale/Link to Restoration

Seabird, marine mammal, and fish resources throughout the spill area, and particularly in Prince William Sound (Bue et al. 1998) were damaged by the 1989 *Exxon Valdez* oil spill (EVOS) and have not fully recovered (1998 EVOS Trustee Council Status Report). This project has potential for improving long-term monitoring and management of fish and marine mammal resources within the spill area and statewide. Improved resource monitoring will enable more effective evaluation of recovery efforts. It will also facilitate improved in-season management of fisheries, which will help restore injured sport, commercial, and subsistence fishing services.

Location

This project will be conducted in waters of Kachemak Bay in Lower Cook Inlet (Southern Kenai Peninsula). However, project benefits will be realized throughout the spill area along the northern Gulf of Alaska through a greater understanding of ecosystem functions.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Port Graham, Seldovia, and Nanwalek residents have a long history of using these fish resources for commercial and subsistence purposes and are concerned for the area's continuing productivity.

PROJECT DESIGN

A. Objectives

1. FY02 - Compare catch composition from different survey gears on years of survey overlap to determine the relative fishing power of each gear type.

2. FY02 - Use gear selectivity information to develop recommendations to improve the utility of trawl surveys to monitor and detect annual and long-term changes in the marine ecosystem along the northern Gulf of Alaska;

3. FY02 - Develop tools, technologies, and information that can help resource managers and regulators improve management of marine resources and address problems that may arise from human activities.

4. FY03 – Project Closeout; Final report writing and dissemination.

B. Methods

Both historical trawl surveys involved 1-nautical mile tows within Kachemak Bay in lower Cook Inlet. The small-mesh survey used a high-rise trawl net with a 20.1 m (66-feet) headrope rising 18.3 m (61 feet) above the substrate and 32-mm (1¼ inch) mesh throughout (Davis 1982; Gustafson 1994). The larger-mesh survey used a trawl net with a 21.3-m (70-feet) headrope rising 2.7 m (9 feet) above the substrate and mesh measuring 102 mm (4 inch) in the wings and body, 89 mm (3½ inch) in the intermediate and cod end, and 32 mm (1¼ inch) in the cod end liner (Bechtol 2001). Following each tow, the tared catch weight was obtained, then the catch dumped on deck. After the tared catch weight was obtained, the entire catch was sorted, counted, and weighed by species or major species group with the total catch subsampled as necessary.

The null hypothesis is that fish species composition, abundance, and biomass is consistent among years and survey types. All catch data will be standardized to 1.0 nm equivalents and summarized by tow. General fish catch will be converted to kg/nm and percent catch composition. Biometric analyses will compare catch composition between small-mesh and large-trawl surveys.

Cooperating Agencies, Contracts, and other Agency Assistance

Information generated by this trawl study will also be used by the USF&WS, Biological Resources Division, in conjunction with ongoing seabird foraging studies. The project Principal Investigator will also coordinate activities and results with scientists from Biological Resources Division, U.S. Geological Survey; National Marine Fisheries Service, Alaska Fisheries Science Center; and U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge.

SCHEDULE

Measurable Project Tasks for FY02

October-November	Error checking and additional computer entry of historical survey data.
November-January	Comparative analyses of historical survey data; modify analytical approach as is appropriate.

January-April	Preparation of results for initial review; development of recommendations to improve the utility of future trawl surveys and survey data; turn in EVOS Annual Report, DPD, and budget for FY03 activities.
May-September	Additional data analyses, report writing, and dissemination of final results.
September	Submit result to peer-reviewed journal.

Measurable Project Tasks for FY03

October-December	Completion of of EVOS Final Report.
November:	Present results at AFS meeting.
January:	Present results at annual EVOS workshop and submission of EVOS Final Report.

Project Milestones and Endpoints

December 2001	Objective 1-2: Collect survey data and conduct preliminary analyses.
September 2002	Obj. 1-4: Develop recommendations for future surveys, including an analysis of the utility of different trawl gears for resource monitoring; submit project results to peer-reviewed journal.
January 2003	Completion of final report.

Completion Date

All project objectives will have been met and the project will close out by the end of FY03.

PUBLICATIONS AND REPORTS

Internal (ADF&G) and external (EVOS Trustee Council, Chief Scientist, etc.) peer review of project documents (DPD, Annual and Final Reports) will occur throughout the project's duration. We will seek to present significant findings at scientific symposia (e.g., American Fisheries Society Meeting) and publish of findings in a peer-reviewed journal (e.g., Transactions of the American Fisheries Society). At least five presentations and manuscripts have already resulted from related projects during FY96-99.

PROFESSIONAL CONFERENCES

Travel funds are requested to attend the EVOS annual workshops in Anchorage. In addition, results will be presented at the annual meeting of the Alaska Chapter of the American Fisheries Society.

NORMAL AGENCY MANAGEMENT

This project coordinates and assists in acquisition of multivariate ecosystem data to aid ADF&G and other agencies with the quantification and analysis of spatio-temporal trends in abundances forage fishes and invertebrates. These activities are critical to on-going analyses and population assessment modeling for marine birds and mammals and for judging the effects of the EVOS on them. Without support for this project our ability to conduct and support analysis of this unique and standardized 25 year data series will be severely impaired. These analyses are essential for the understanding of how forage fish abundance may have affected the dynamics of marine birds and mammals. It is against this background of ecological change that effects of the EVOS must be objectively considered. This project combines the framework for agencies to cooperate in solving problems together, with each contributing unique and necessary assets to solve these larger problems. Along with monitoring the recovery of injured resources, the proposed project will improve and compliment the department's ability to assess and manage fisheries resources within the spill area and elsewhere in Alaska. Without the Trustee Council's financial support, this project is not likely to receive agency funding in the near future.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This study addresses a number of issues related to other components of a wide variety of ecosystem projects. Direct project coordination with Cook Inlet Seabird and Forage Fish Study, and Ecology and Demographics of Pacific Sandlance (Both projects under direction of Biological Resources Division (BRD) of U.S. Geological Survey (USGS)). Project database component for PWS has been provided to Tracey Gotthardt, a graduate student under Dr. Kathy Frost studying dietary changes in Harbor seals. In FY98, the project data was provided to Dr. Jennifer Purcell in order to analize the changes in jellyfish over time.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

Does not apply.

PROPOSED PRINCIPAL INVESTIGATOR

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PRINCIPAL INVESTIGATOR

William R. Bechtol, Research Project Leader for salmon and herring in Lower Cook Inlet and groundfish and shellfish in Cook Inlet and Prince William Sound for the Alaska Department of Fish and Game, Division of Commercial Fisheries, 3298 Douglas Place, Homer, AK, 99603.
Education: Master of Science, Fisheries, University of Alaska, 1990. Bachelor of Science, Wildlife Science, University of Washington, 1979.
Professional Experience: 1996-present: ADF&G, Commercial Fisheries, Research Project Leader, 1995-present: Primary responsibilities include assessment and research of commercial groundfish and shellfish in Cook Inlet, Prince William Sound, and state waters of the Central Gulf of Alaska, and salmon and herring in lower Cook Inlet; design and implement surveys to assess crabs, groundfish, scallops, and clams using trawl, longline, dredge, acoustic, and shovel gears, coordination of onboard observer and port sampling programs; development of age-structured models; development of fisheries regulations and management plans.
1989-1995: Regional Groundfish Biologist, ADF&G, Commercial Fisheries, Homer, Alaska. Responsibilities include research and management of commercial groundfish fisheries in Cook Inlet, Prince William Sound, and state waters of the Central Gulf of Alaska; design and implementation of port, trawl survey, and onboard observer sampling programs; herring egg deposition surveys in Prince William Sound using SCUBA; SCUBA surveys of log transfer facilities; development of fisheries regulations and management plans; (1984-1984) principally involved in design and implementation of jig, line transect, and mark-recapture surveys, including use of SCUBA, to assess pelagic and demersal rockfish resources along the outer Kenai Peninsula.

1980-1989: Fisheries Technician, ADF&G, Fisheries Rehabilitation Enhancement and Development (FRED) Div., Primary responsibilities included design and implementation of limnology surveys, particularly concerning juvenile sockeye rearing in barrier lake systems of lower Cook Inlet and the outer Kenai Peninsula; mark-recapture surveys to assess survival from different juvenile salmon rearing strategies; and aerial surveys to assess salmon escapements.

Fisheries Research Institute, 1979: Field technician in studies of side-scanning and upward-scanning hydroacoustic estimation of sockeye salmon escapement to the Kvichak River, Alaska. American Fisheries Society, Alaska Chapter, Executive Committee, 1990-1992 and 1998-present; currently Alaska Chapter president.

Selected Publications:

North Pacific Fisheries Management Council. *Draft for Council Review.* Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis for Plan Amendment #60 to the Fishery Management Plan for the groundfish fishery of the Gulf of Alaska to prohibit non-pelagic trawl gear in Cook Inlet. Prepared by: J. DiCosimo, **B. Bechtol**, and L. Brannian. NPFMC, 605 W. Fourth Ave., Suite 306, Anchorage, AK 99501.

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Otis, E.O., **W.R. Bechtol,** and W.A. Bucher. 1998. Coping with a challenging stock assessment situation: the Kamishak Bay sac-roe herring fishery. In: F. Funk, T.J. Quinn II, J. Heifetz, J.N. Ianelli, J.E. Powers, J.F. Schweigert, P.J. Sullivan, and C.-I. Zhang [eds]. Fishery stock assessment models. Alaska Sea Grant Report Report No. AK-SG-98-01, University of Alaska, Fairbanks, 1998.

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OTHER KEY PERSONNEL

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LITERATURE CITED

Anderson, P.J., J.E. Blackburn, and B.A. Johnson. 1997. Declines of forage species in the Gulf of Alaska, 1972-1995, as an indicator of regime shift. Pages 531-543 *in* Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report 97-01, University of Alaska, Fairbanks.

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Piatt, J.F., and P. Anderson. 1996. Response of common murres to the *Exxon Valdez* oil spill and long-term changes in the Gulf of Alaska marine ecosystem. Pages 720-737 In: S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright [eds.], *Exxon Valdez* Oil Spill Symposium Proceedings, American Fisheries Society Symposium 18.

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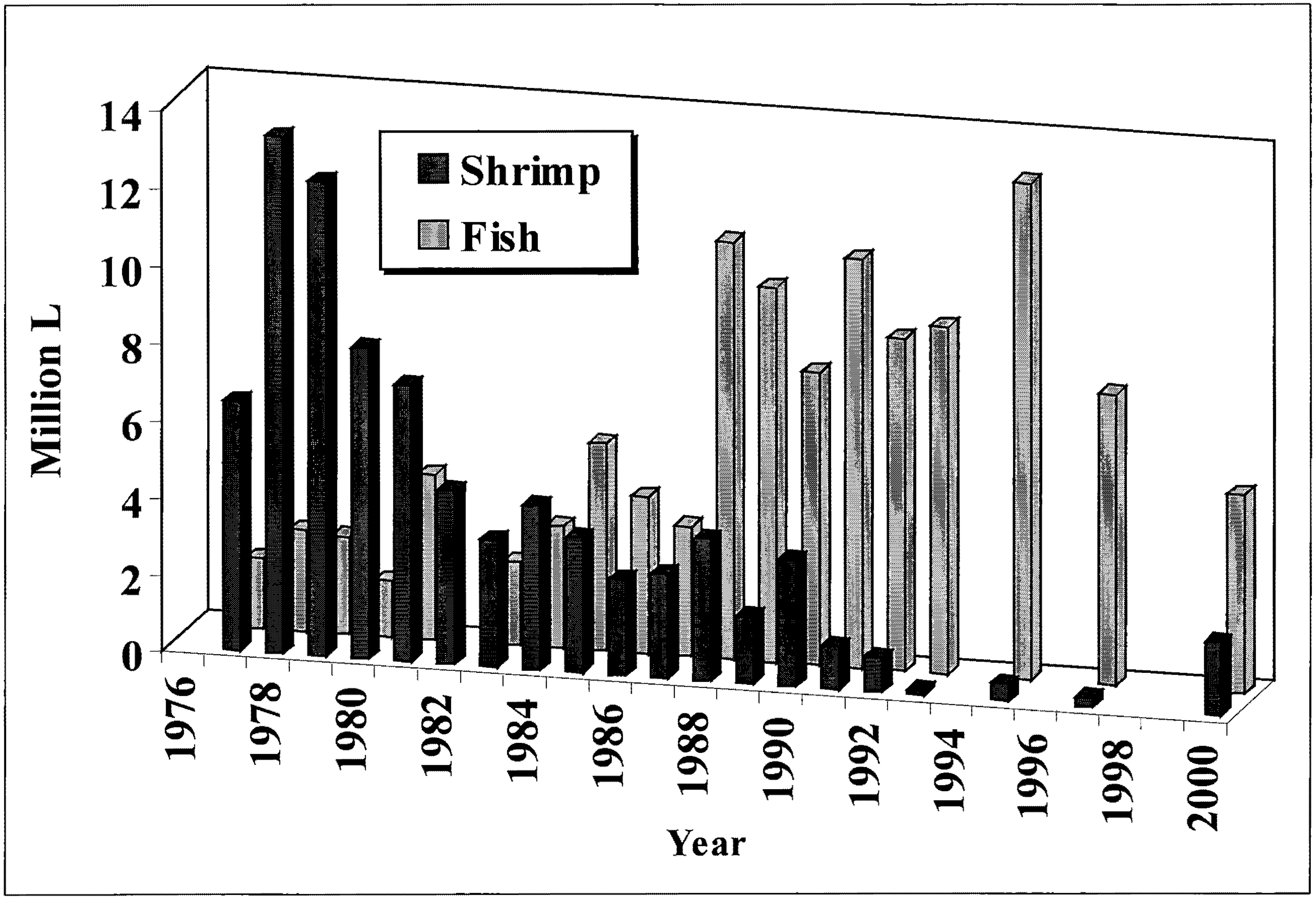

Figure 1. Changes in relative catch composition of shrimp and fish and in frequency of occurrence of gadid species in a small-mesh trawl survey, Kachemak Bay, 1976-2000.

2002 EXXON VALDEZ TRU COUNCIL PROJECT BUDGET
October 1, 200' ptember 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$41.8						
Travel		$2.2						
Contractual		$0.8						
Commodities		$1.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$45.8				Estimated FY 2003	Estimated FY 2004	
General Administration		$6.3						
Project Total	$0.0	$52.1				$15.0	$0.0	
Full-time Equivalents (FTE)		0.8						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY02

Prepared:

Project Number: 02604
Project Title: Gear Selectivity in Trawl Surveys along the Northern Gulf of Alaska
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2002 EXXON VALDEZ TRU COUNCIL PROJECT BUDGET

October 1, 200' --ptember 30, 2002

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 2002
Bechtol	Principal Investigator	18 E	2.0	5.5	0.0	11.0
FB II - Vacant	Project Biologist	16 B	3.0	4.4	0.0	13.2
FWT III - Vacant	Project Technician	11 C	2.0	3.3	0.0	6.6
Biom. II - Vacant	Project Biometrician		2.0	5.5	0.0	11.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		9.0	18.7	0.0	
					Personnel Total	$41.8

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2002
EVOS Meeting	0.2	2	4	0.1	0.8
					0.0
Professional Meeting - Results Dissemination	0.3	2	8	0.1	1.4
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$2.2

FY02

Prepared:

Project Number: 02604
Project Title: Gear Selectivity in Trawl Surveys along the Northern Gulf of Alaska
Agency: Alaska Department of Fish and Game

FORM 3B
Personnel
& Travel
DETAIL

Contractual Costs:	Proposed
Description	FY 2002
Telephone	0.5
Postage/Shipping	0.3
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.8

Commodities Costs:	Proposed
Description	FY 2001
COMPUTER SUPPLIES	0.5
OFFICE SUPPLIES	0.5
Commodities Total	$1.0

FY02

Prepared:

Project Number: 02604
Project Title: Gear Selectivity in Trawl Surveys along the Northern Gulf of Alaska
Agency: Alaska Department of Fish and Game

FORM 3B
Contractual &
Commodities
DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2002
			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: Description	Number of Units	Inventory Agency

FY02

Project Number: 02604
Project Title: Gear Selectivity in Trawl Surveys along the Northern Gulf of Alaska
Agency: Alaska Department of Fish and Game

FORM 3B
Equipment
DETAIL

Prepared:

Permanent Archiving of Specimens Collected in Nearshore and Deep Benthic Habitats

Project Number:	02608
Restoration Category:	Monitoring
Proposer:	University of Alaska Museum
Cooperating Agencies:	
Alaska SeaLife Center:	no
Duration:	1st year, 1-year project
Cost FY 02	$ 104,465
Geographic Area	Prince William Sound
Injured Resource/Service:	Nearshore and deep benthic ecosystems

ABSTRACT

This project is intended to support acquisition and archiving of marine invertebrate specimens collected as part of EVOS assessment studies in Prince William Sound and environmental monitoring in Port Valdez between 1990 and 1995. Specimens represent a time series of samples from eelgrass habitats, kelp forest habitats, deep benthic communities. As a result of these efforts, there will be an improved set of baseline data for the marine biota of Prince William Sound.

INTRODUCTION

This project will support acquisition and archiving in the University of Alaska Museum (UAM) of collections made by the University of Alaska School of Fisheries and Ocean Sciences from the nearshore subtidal and benthic environments of Prince William Sound. The project will address the need to "analyze and synthesize existing data sets." including "collections of specimens and archived samples." described in the RFP. Specimens and samples archived at the UAM will be included in a system that assures their perpetual availability to the scientific community. The disposition of samples and documentation of scientific work based on them will be available on the Museum's website. At least one paper describing range extensions and biogeography will be prepared.

NEED FOR THE PROJECT

A. Statement of Problem

Collections made by the University of Alaska School of Fisheries and Ocean Sciences represent an extensive survey of the invertebrate fauna of Prince William Sound (Jewett et al. 1994; Feder and Blanchard, 1998). The physical condition of the specimens is excellent, and locality and taxonomic information are available with each, but this valuable collection and its associated data are not easily accessible, either to EVOS stakeholders or to scholars, and their long-term care is not assured. Unless collections are archived, they could be lost, neglected or ruined.

The scientific value of these specimens has been established. A subset representing nearshore subtidal habitats was re-examined as part of research on potential introductions of nonindigenous species into Prince William Sound, (Foster, chapter 9E in Hines et al. 2000). For that project, annotated species lists were developed to help taxonomic experts establish a baseline for the status of nonindigenous species in Prince William (Foster and Feder, Chapter 10 in Hines et al. 2000). One hundred two species records in the data sets are derived from the EVOS specimens. Thirteen species are potentially undescribed, and seven are the first records of the species' occurrence in Alaska. The deep benthic samples are the physical documentation of Feder and Blanchard's (1998) paper on the effects of the oil spill on deep benthos, and of temporal changes in the benthic fauna of Port Etches, Rocky and Zaikof bays (Hoberg and Feder in press).

B. Rationale/Link to Restoration

The proposed project is closely linked to both the research and the monitoring needs of restoration. Because these specimens are the physical documentation of resources present in Prince William Sound, they are essential to assessment and to monitoring studies (such as GEM) which depend on accurate identifications for their scientific validity. As a result of these efforts, there will be an improved set of baseline data for the marine biota of Prince William Sound. These data will be both the physical specimens, available for teaching and research, and a remarkable set of geographical and time series data on distribution of marine invertebrates in biologically important subtidal habitats.

This new set of specimens will be a valuable addition to the systematic collections at the UAM which have been active and growing, particularly in the past decade. The UAM's biological collections will continue to expand in the near future through UAM's Arctic Archival Observatory. Through this project, all of the UAM's scientific collections will be brought into a single georeferenced database with extensive Worldwide Web interfaces for querying and mapping results. In addition to "label data" the database will include extensive information on how individual specimens were generated and how they have been used in subsequent investigations. In June of 2001, a new Curator of Fishes will join the UA Museum staff and assume some of the responsibility for marine collections. Additionally, the Museum's long-term plan includes hiring a curator for marine invertebrates in FY 2003. The UAM is expanding its capacity for housing regional natural history collections with a 30-million dollar expansion campaign intended to approximately double the size of the existing structure.

C. Location

This work will take place at the University of Alaska Fairbanks. The project should benefit scientists, the lay public, educators, and subsistence users working in the sound and Gulf of Alaska coast areas. Further, the Museum's marine invertebrate collections are accessible to the world-wide scientific community.

PROJECT DESIGN

A. Objectives

The project's objectives are to:

1. Keep specimens and associated locality data collected as part of oil spill studies from being lost.
2. Make information based on the specimens (that is, species composition and distribution of Prince William Sound and Gulf of Alaska marine invertebrate fauna) available to stakeholders.

B. Methods

The specimen archive addressed here consists of alcohol-preserved specimens stored in vials within taped plastic bags. They have been sorted by taxon and locality. The physical condition of the specimens is excellent, locality and taxonomic information are available with each. There are 30 "banker' boxes" which contain specimens collected from nearshore subtidal sites, and 90 five-gallon buckets containing the deeper benthic specimens. There are about 800 specimens per box or bucket.

The nearshore subtidal specimens represent a time series for four localities in Prince William Sound, Drier Bay, Lower Herring Bay, Moose Lips Bay, and Mallard Bay. Collections were made in 1990, 1991, 1993, and 1995. Specimens were collected by divers at three depths, (to 20 meters) within eelgrass beds. Identification to genus and species level was accomplished at the University of Alaska School of Fisheries and Ocean Sciences, with additional taxonomic assistance from Nora Foster, UA Museum and Dr. Jerry Kudenov, University of Alaska Anchorage.

The deep benthic specimens were collected in 1990 and 1991 by Howard Feder and Arny Blanchard, at 20 and 100 meter depths in the vicinity of Knight Island, seven sampling stations represent the oil spill trajectory, seven were outside the oil spill area. Samples from Port Valdez represent the stations within Port Valdez occupied over several years as part of environmental monitoring of the pipeline terminal and port. Similarly, the specimens are identified to genus and species level.

Incorporating the collections into the UA Museum Collection involves three tasks: accessioning, in which permanent records are created for assemblages of specimens to which the museum has title; cataloging, in which individual specimens are assigned numbers and entered as records in an electronic catalog; and finally the specimens are placed within the museum shelves, usually in taxonomic order. As part of cataloging, the specimens will be screened for quality, so that fragmentary, damaged or otherwise inappropriate specimens will not be retained. Quality screening will reduce the actual number of specimens acquired by over 50%. The cataloging process leads easily into the basis for a paper on range extensions and biogeographic relationships of Prince William Sound invertebrate fauna, and a draft could be completed within the first year of funding.

This project's highest priority is the collections made in the nearshore subtidal habitats. If the Trustees can fund only a smaller-scale project, a smaller budget, (ca. $63,000) and shorter timeline can be considered by the proposers.

C. Cooperating Agencies, Contractors, and other Agency Assistance

The University of Alaska School of Fisheries and Ocean Sciences will donate the specimens and copies of associated locality data to the Museum. Max Hoberg, a Technician with the School of Fisheries will work on this project at the Museum.

SCHEDULE

A. Measurable Project Tasks for FY 02 (October 1, 2001- September 30, 2002)

November 30: Accession numbers assigned, accession log created

January 13-23:	Attend annual restoration workshop
March 30:	Specimen labels prepared
April 1:	Specimens unpacked, sorted by taxon
April 15:	Complete annual report to EVOS Trustees
August 1:	Specimens sorted, labeled and incorporated into Museum shelving
July 30:	All species locality data available to Gordon Jarrell to incorporate into Arctic Observatory database
August 30 31:	Complete manuscript on distribution of marine mollusks and polychaetes

B. Project Milestones and Endpoints

1. Keep specimens and associated locality data collected as part of oil spill studies from being lost. This objective will be met by November 30, when specimens will be physically in the Museum and accessioned.
2. Make information based on the specimens (that is, species composition and distribution of Prince William Sound and Gulf of Alaska marine biota) available to stakeholders. This objective will be addressed by August 30 when a manuscript on the distribution of marine mollusks and polychaetes will be completed; it will be met when the publication has been accepted by a peer reviewed journal.

C. Completion Date

All milestones, except acceptance the resulting paper by a peer-reviewed journal will be completed within the fiscal year (before September 30, 2002).

PUBLICATIONS AND REPORTS

An annual report to the Trustees Council will be submitted by April 15, as required by the Invitation to Submit Proposals. A paper on distribution and habitats of subtidal annelids and mollusca (title and co-authorship to be determined), could be submitted to the following journals: the Veliger, International Review of Hydrobiology, or other journals to be considered.

PRINCIPAL INVESTIGATOR

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QUALIFICATIONS OF PRINCIPAL INVESTIGATOR

Education
University of Alaska B.S., 1969 Biological Sciences
University of Alaska M.S., 1979 Biological Oceanography

Employment
1999-present Coordinator, Aquatic Collection, University of Alaska Museum (part-time affiliate)
1997-present Taxonomic consultant, self-employed
1997 Project Manager/Biologist, Prince William Sound Science Center, Cordova, Alaska
1981-1997 Coordinator, Aquatic Collection University of Alaska Museum

Selected Reports and Publications
Lee, R. S. and N. R. Foster. 1985. A Distributional List with Range Extensions of the Opisthobranch Gastropods of Alaska. The Veliger 27(4):440-448.
Juday, G. P. and N. R. Foster. 1990. A preliminary Look at the Effects of the Exxon Valdez Oil Spill on Green Island Research Natural Area. Agroborealis 22 (1):10-17.
Foster, N. R. 1991. Intertidal Bivalves: A Guide to the Common Marine Bivalves of Alaska. University of Alaska Press. 152 pp.
Feder, H. M., N. R. Foster, S. C. Jewett, T. J. Weingartner, and R. Baxter 1994. Distribution of Mollusks in the Northeastern Chukchi Sea. Arctic 47(2):145-163.
Scheel, D., N. R. Foster, and K. Hough 1998. Habitat and Biological Assessment: Shepard Point Road and Port Project. Report to the City of Cordova, Alaska. Prince William Sound Science Center, Cordova, Alaska. (www.pwssc.gen.ak.us/~shepard).
Goddard, J. H. R. , and Foster, N. R. [in preparation] Range extensions of saccoglossan and nudibranch molluscs (Gastropoda: Opisthobranchia) to Alaska. Sibmitted to the Veliger March 2001.

Experience and Interests:
Taxonomy, ecology, and biogeography of marine invertebrates of the north Pacific and Arctic; care of invertebrate collections, zooarchaeology of shellfish

OTHER KEY PERSONNEL

Max K. Hoberg
Responsibilities: Manage project on day-to-day basis; assign accession numbers to specimens, enter data; unpack boxes; sort specimens by taxon; screen for quality; arrange in systematic order; design, print labels; order supplies.

Gordon H. Jarrell
Responsibilities: Assure that data generated by this project is compatible with other Museum cataloging projects, especially the Arctic Observatory database; design computer printed labels and data interfaces for input and query of the database.

Howard M Feder
Responsibilities: Contribute ideas and co-author paper on distribution of marine benthos.

LITERATURE CITED

Feder, H. M. and Blanchard, A. 1998. The deep benthos of Prince William Sound, Alaska, 16 months after the Exxon Valdez oil spill. Mar. Pollut. Bull. 36: 118-130.

Hines, A. H., G. M. Ruiz, J. Chapman, G. I. Hansen, J. T. Carlton, N. Foster & H. M. Feder. 2000. Biological invasions of cold-water coastal ecosystems: ballast-mediated introductions in Port Valdez / Prince William Sound, Alaska. Final Report to the Prince William Sound Citizen's Advisory Council, U.S. Fish and Wildlife Service and National Sea Grant Program.

Hoberg, M. K. and Feder, H. M. In press. The macrobenthos of sites within Prince William Sound, Alaska, prior to the Exxon Valdez oil spill. International Review of Hydrobiology.

Jewett, S. C., Dean, T. A, Smith R. O., Stekoll, M., Haldorson, L. J., McDonald, L., and Laur D. R., 1995. The effects of the Exxon Valdez Oil Spill on Shallow Subtidal Communities in Prince William Sound, Alaska, 1989-93. Restoration Project 93047 (Subtidal Study 2A) Final Report to the Alaska Department of Fish and Game.

Budget Category:	Authorized FY 01	Proposed FY 02
Personnel		59.83
Fringe Benefits		17.05
Travel		0.44
Services		0.25
Commodities		6.00
Equipment		
Subtotal		83.57
Indirect		20.89
Project Total		104.47
Full-Time Equivalents		1.3

ts are shown in thousands of dollars

LONG RANGE FUNDING REQUIREMENTS
Estimated FY 03

Other Funds		

Coments:
The indirect rate is 25% charged by the University of Alaska
All travel is for attendance at the annual restoration workshop

FY 02

Project Number: 02608
Project Title: Permanent Archiving of Specimens Collected in Nearshore and Deep Benthic Habitats
Name: University of Alaska Museum

FORM 4A
Non-Trustee
SUMMARY

Prepared: 9-Apr-01

Personnel Costs:				Months Budgeted	Monthly Costs	Overtime	Proposed FY 02
	Name	Position Description					
	N. Foster	*Coordinator, Aquatic Collection		4	$3,375.00		$13,500.00
	M. Hoberg	Technician @18.52/hr + 20.3% leave		12	$3,861.00		$46,332.00
			Subtotal				$59,832.00
Staff Benefits:							
	* Nora Foster 4 months at 520 hours x $19.47 justified because she does not receive salary support from the University of Alaska Museum benefit rate of 7.9% is used for temporary employees						
	Foster						$1,066.50
	Hoberg						$15,984.00
						Personnel Total	$76,882.50

Travel Costs:						
	Description	Ticket Price	Round Trips	Total Days	Total Per Diem	Proposed FY 02
	Foster- to Anchorage to attend restoration workshop	$200.00	1	2	$120.00	$440.00
					Travel Total	$440.00

FY 02

Project Number:
Project Title: Permanent Archiving of Specimens Collected in Nearshore and Deep Benthic Habitats
Name: University of Alaska Museum

FORM 4B
Personnel & Travel
DETAIL

Prepared: 9-Apr-01

Contractual Costs:	Proposed
Description:	FY02
communication and printing	$250.00
Contractual Total	$250.00

Commoditions Costs:	Proposed
Description:	FY02
We will require jars of various sizes, from .5 to 3 liters. We estimate each lot will require .25 liter of ethyl alchol. We will also need appropriate paper for archival labels.	$6,000.00
Commodities Total	$6,000.00

FY 02	Project Number: Project Title: Permanent Archiving of Specimens Collected in Nearshore and Deep Benthic Habitats Name: University of Alaska Museum	FORM 4B Contractual and Commodities DETAIL

Prepared: 9-Apr-01

02609

Long-Term Temperature/Salinity Monitoring Within the Alaska Coastal Current

Project Number:	02609
Restoration Category:	Monitoring
Proposer:	University of Alaska Fairbanks
Lead Trustee Agency:	ADFG
Cooperating Agencies:	none
Alaska SeaLife Center:	no
Duration:	1st year, 2-year project
Cost FY 02:	$55,918
Cost FY 03:	$15,509
Geographic Area:	Resurrection Bay/Gulf of Alaska shelf
Injured Resource/Service:	All organisms and services

ABSTRACT

Interannual variations in temperature, salinity, and their vertical distribution on the northern Gulf of Alaska shelf reflect environmental changes that might affect this marine ecosystem. This variability needs to be quantified and understood based on extended time series such as the 30-year record at hydrographic station GAK1 near Seward. This project maintains this time series and will continue to quantify the variability and understand the sources of it. It will also begin to document interannual variations in near-surface (upper 10 m) stratification and the timing of the spring bloom on the inner shelf. The data and associated analyses are suggested as being an important component to the development of the GEM program.

INTRODUCTION

This proposal seeks to continue the hydrographic measurements needed to maintain the 30-year (1970 – present) time series of conductivity-temperature versus depth (CTD) data collected at hydrographic station GAK1 on the northern Gulf of Alaska shelf. EVOS support for this program began in November 1997 with monthly cruises to station GAK1. These are presently scheduled to continue through September 2001. The monthly data are being supplemented with hourly (or shorter) measurements of temperature and conductivity at six depths using instruments moored at station GAK1. Weingartner (1999, 2000, and 2001) gives a more complete description and analysis of the data collected thus far. However, the principal findings to date are:

1. The anomalous summer 1997 warming (amounting to 1-2°C above normal) was confined to the upper 40 m of the ocean. That warming was mainly a result of anomalously clear skies and low winds during the summer of 1997.
2. The abnormally large El Niño-related winter 1998 warming (~2°C) occurred throughout the entire 250 m depth of the shelf. The return to near normal temperatures beginning last May and continuing through the present is being documented.
3. The abnormally large El Niño-related winter 1998 freshening (amounting to a vertically averaged salinity decrease of 0.15 psu) over the upper 200 m of the shelf. Freshening ceased in May and, below 200 m, was replaced with the saltiest waters ever observed at this location. These high salinity waters are enriched in nutrients and potentially available to phytoplankton in the surface layers.
4. A return to near normal temperatures in the summer after May 1998.
5. The integral time scales for temperature and salinity at GAK1 are about 1 month, which implies that the monthly values (which comprise the historical data set) are not severely aliased.
6. Within-month temperature and salinity variance computed from the moored instruments is no greater than the interannual variability based on the monthly data from the historical record.
7. Variations in freshwater forcing and the baroclinic transport of freshwater are large on seasonal, interannual, and interdecadal time scales. On average freshwater transport increases fivefold between spring and fall. Alaska Coastal Current freshwater transport in spring 1998 (during the 1997-98 El Niño) was twice that of spring 1999.
8. A first order description of seasonal variations in freshwater transport of the Alaska Coastal Current shows that these variations are accounted for by the annual cycles of: 1) coastal discharge and 2) the Ekman onshore transport of relatively fresh surface waters. Their sum accounts for the annual cycle of the baroclinic component of the freshwater transport within the Alaska Coastal Current. This transport primarily occurs within the upper 150m of the water column and within 35 km of the coast.
9. The Alaska Coastal Current could significantly influence the marine ecosystem on the southeast Bering Sea. Our preliminary estimate is that the Alaska Coastal Current contributes about 25% of the Bering Sea freshwater supply. Therefore, improved understanding of environmental variability of the Gulf of Alaska ecosystem could improve our understanding of changes in the Bering Sea ecosystem.

10. Time series of coastal discharge estimates based on Royer's (1982) method, measured discharge, the leading EOF of precipitable water over the Northeast Pacific Ocean, and coastal salinity data all suggest a decrease in freshwater discharge into the northern Gulf of Alaska from the late 1950s through the mid-1970s. Discharge increased from the mid-70s through the early-80s; coincident with the regime shift of the 1970s and with the Pacific Decadal Oscillation (PDO) (Mantua, 1997; Overland et al., 1999). These findings add to other suggestions of a freshening across the North Pacific Ocean basin since the 1970s (Wong et al., 1999).
11. Monthly anomalies in the PDO index are coherent with Royer's monthly discharge anomalies at periods of 2 - 4 years suggesting a possible relationship to El Niño events.
12. Monthly sea level anomalies at Seward Alaska are significantly correlated with monthly anomalies of vertically integrated (0-200m) salinity and the 0/200db dynamic height. Hence sea level could serve as a proxy for shelf salinity variations here and perhaps elsewhere in the Gulf of Alaska. The Gulf of Alaska watershed and coastal ocean are severely undersampled with respect to precipitation, river discharge, and salinity. Long-term time series of these are lacking and even the future maintenance of existing discharge and weather stations is uncertain. There is a need to develop proxy variables that can be used to reliably estimate runoff and coastal salinity. A goal of this EVOS program is to determine if sea level can serve as a proxy for ocean salinity variations.
13. There is a promising correlation emerging between GAK 1 dynamic height (0/200 db) and the freshwater and mass transport as computed from the cross-shore density field in the Alaska Coastal Current. This suggests that the GAK 1 data could be used as an index for these variations.
14. We continued our investigations into the reasons for the anomalously low-salinity shelf water observed during the winter of 1998 and suggest that this was a consequence of several factors. First, there was above average seasonal (fall and winter) coastal discharge from Alaska. Second, there was also above average discharge from the Pacific Northwest as represented by the discharges from the Fraser River in British Columbia and the Columbia River in Oregon in the preceding summer and early fall. Third, there was anomalously strong seasonal coastal downwelling around the coastal Gulf of Alaska. These factors enhanced one another in several ways. The high runoff diluted inner shelf waters and strengthened the cross-shelf density gradients. These gradients, in conjunction with the strong cyclonic wind stress, enhanced the alongshore extent and strength of the coastal current. The anomalously strong downwelling would also have enhanced trapping of freshwater against the coast and augmented coastal freshening by increasing the onshore transport of low-salinity surface waters. Furthermore, our results suggest that the simultaneous occurrence of all of these anomalies is unusual because 1997-98 was the only year since 1970 in which all of these anomalies coincided.

We propose to continue the measurement program at GAK1 as we have done in the past with but a modest change.

The GAK1 environmental data appear 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. The measurements will also provide a bridge to the Gulf Ecosystem Monitoring Program now under development. 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. As a PI on the Gulf of Alaska GLOBEC program, I have shared data (and sampling resources) from both programs to build a better understanding of the physical environmental variability of this shelf. 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. GLOBEC monitoring began in the Gulf of Alaska in October 1997, and is continuing through 2004 in conjunction with process and model studies. 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. **Figure 2** shows the mean annual precipitation amounts at selected National Weather Stations coastal stations around the Gulf of Alaska and the Pacific Northwest and in the interior of the gulf as estimated by Baumgartner and Reichel (1975). Annual precipitation rates (> 3m/yr) are largest in the northern (Prince William Sound) and eastern gulf (Southeast Alaska and northern British Columbia) relative to other areas. 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 British Columbia to Kodiak Island (Royer, 1982). The seasonal variability in winds and freshwater discharge (**Figure 3**) is large. (Winds are represented in **Figure 3** 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 westward winds and positive values imply eastward winds). 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 3**) 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).

The shelf hydrography and circulation vary seasonally and are linked to the annual wind and freshwater discharge cycles. **Figure 4** contrasts the cross-shore salinity structure in April, August, and December within the Alaska Coastal Current. (Density gradients are important in ocean dynamics and salinity is the predominant influence on ocean density in the Gulf of Alaska.) In April, the vertical and cross-shore density gradients are weak and the front (~10 km offshore) intersects both the surface and the bottom. In August, the vertical density gradients are strong but the cross-shore density gradients are relatively weak and the front is confined to the uppermost 40 m and has spread ~40 km offshore. In December, the stratification is moderate, the cross-shore density gradients are large and the front forms a 30-km wide wedge adjacent to the coast. These different frontal structures imply seasonally varying dynamics (e.g., Yankovsky and Chapman, 1997; Chapman and Lentz, 1995) that affect the transport and dispersal of dissolved and suspended material across the shelf. For example, surface drifters released seaward of the ACC drifted onshore (in accordance with Ekman dynamics). Upon encountering the ACC front, they moved in the alongfront direction, which is consistent with the geostrophic tendency implied by the cross-shore density distributions of **Figure 4** (Royer et al, 1979). Inshore of the ACC front, the surface layer spreads offshore as discharge increases (Johnson et al., 1988). This cross-shelf circulation pattern could accumulate plankton and attract foraging fish. **Figure 4** also shows that near-bottom salinities are higher in summer than in spring and, in fact, maximum bottom salinities occur in fall coincident with minimum surface salinities and maximum inshore stratification (Xiong and Royer, 1984). The source of the high salinity water is the onshore intrusion of slope water when downwelling relaxes in summer (Royer, 1975, 1979). Simple 2-D models of this shelf suggest that the dense water is mixed upward in winter to supply the surface layers with nutrients in early spring (Williams and Weingartner, 1999). The swiftest along shore 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 is consistent with the finding that monthly coastal sea level anomalies at Seward are significantly correlated with upper ocean dynamic height (a function of the vertically integrated ocean density) and vertically averaged salinity anomalies at GAK1 (Weingartner et al., 2000). Horizontal gradients of dynamic height are proportional to the pressure gradients that accelerate ocean currents and provide an estimate of the oceanic transport. These findings are 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. Royer (1979) also found that sea level and precipitation anomalies were well correlated.

Our results are suggesting that there is a relationship between monthly (and perhaps shorter period) *cross-shelf dynamic height (or upper ocean density) gradients* and a number of other variables including winds and/or freshwater discharge. For example, we are finding that there is a significant positive correlation between monthly anomalies in 0/100 db Alaska Coastal Current baroclinic transport and inner shelf (eventually GAK1) dynamic heights. The relationship appears to vary seasonally (although the number of degrees of freedom is small in some seasons): it is largest in fall and early spring ($r > 0.8$), negligible in summer, and negative in winter. Although these findings are promising I do not understand the seasonal changes in the correlations. I suspect that, if real, the seasonally changing correlation is related to the coastal current's response to seasonal changes in winds and discharge, which is unlikely to be linear. Nevertheless, if a reliable relationship can be constructed between GAK1 dynamic height and Alaska Coastal Current transport, then it might be possible to predict mass and freshwater transports (on at least monthly or longer time scales) from a single hydrographic station or mooring on the inner shelf. We also know that freshwater discharge (Royer, 1982; Weingartner et al., 2000) and winds (Livingstone and Royer; 1980) are coherent over a broad along shore distance. In addition, the integral time scales of temperature and salinity (calculated from the EVOS-supported mooring at GAK1, Weingartner, 1999), are about one month on this highly advective shelf. Because of the broad spatial scales of the forcing and the long integral time scales in temperature and salinity, it might be possible to construct one or two monitoring sites around the gulf that are representative of a broad along shore region of the shelf. If so the results would be useful for ecosystem monitoring, model evaluation (and perhaps data assimilation) and retrospective studies.

It seems 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 4 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 5**). 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 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. At that time 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 30-year time series for this station. Sampling became more routine (~monthly) in the early 1990s with support from NOAA and the use of a 25-foot vessel (*Little Dipper*) operated by the University of Alaska's Institute of Marine Science. EVOS support has systematized the sampling further and the mooring is yielding crucial new information on temporal variability in the thermohaline structure of this shelf. 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). Vance et.al. (1998) showed that the unusually warm surface waters prevalent throughout the Gulf of Alaska and the Bering Sea in the summer of 1998 were accompanied by observations of species typically associated with mid-latitudes and, in the case of the Bering Sea, with massive changes in the ecosystem.

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. Other EVOS-supported investigators studying murre nesting variability (Kettle et al., 1999) have used the data collected recently at GAK1. Warm ocean temperatures enhance survival of young-of-the-year salmon (Willette et al., 1999) and overwintering herring (Norcross et al., 1999). Pollock are important predators on smaller-sized juvenile salmon. Under cold conditions, salmon grow slowly, therefore remaining smaller longer and hence more susceptible to predation than under warm condition when growth rates are more rapid (Willette et al., 1999). We emphasize that upper ocean temperature anomalies are not always correlated with subsurface temperature anomalies, thus measurements are needed to understand how environmental variability is reflected throughout the water column.

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) and possibly reflecting the PDO signature. Weingartner et al. (2000) also show that much of the low frequency variability is coherent with the PDO signature at periods of 2 – 4 years (the El Niño time scale). Changes in upper ocean salinity could affect circulation in the Alaska Coastal Current and also influence biological production by varying frontal properties, circulation strength, the vertical stratification of the water column, and the nutrient concentrations. All of these properties showed considerable differences during the fresh, warm spring of 1998 compared to the salty (but near normal temperatures) of spring 1999 (Weingartner, 2000). The GAK1 data also show substantial interannual variations in bottom water salinities, although these are not correlated with variations in surface salinity. The lack of a correlation is not unexpected because near-bottom salinities are linked to shelfbreak processes, while surface variations are associated with precipitation and runoff. Ruehs et al. (1999) are finding that salinity and NO_3 concentrations are positively correlated (**Figure 6**) so that variability in deep water salinity on the shelf probably mean interannual differences in nutrient supply. The GLOBEC program is providing a detailed and year-round description of the nutrients on the Gulf of Alaska shelf. As the size of the data set increases, more reliable salinity–nutrient relationships can be established. If these are robust then 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 are being 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 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 forms 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. The data will also support ongoing efforts to assess the recovery of marine species and services affected by the oil spill. Indeed, several EVOS-supported investigators underscored the need to understand natural climate variability and its influence on the recovery of species injured by the oil spill (Purcell et al., 1999; Piatt and Irons, 1999; Duffy, 1999; Anderson et al., 1999). 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 needing 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 fieldwork 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 those desiring 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.

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. We are seeking cost-effective ways to relay this data onshore in near real-time, possibly in conjunction with the Alaska SeaLife Center. If technical obstacles can be overcome, we will seek a future upgrade to the GAK1 mooring so that these (and possibly other) data can be transmitted directly to Seward for immediate use and display via the Internet.

PROJECT DESIGN

A. Objectives

There are two objectives at the heart of this program. First, we want to continue the 30-year time series at station GAK1 through a combination of monthly CTD measurements and through yearlong deployments of a mooring containing temperature and conductivity (T/C) recorders. We view the maintenance of this time series as essential to the broader goals of GEM. Second, we want to contribute to the design of a cost-effective monitoring program for the Gulf of Alaska shelf. The sampling schemes complement one another with one providing high vertical resolution at monthly time scales and the other providing high temporal but relatively low vertical resolution. Our generic goal of ecosystem monitoring is a long-term undertaking requiring multiple and multi-disciplinary efforts, however, the proposed modest effort constitutes one essential step toward that goal. Toward this broader goal we envision the GAK 1 mooring as eventually incorporating a diverse suite of biophysical sensors that will contribute toward ecosystem monitoring in the Alaska Coastal Current domain of the Gulf of Alaska. Thus, we are requesting a modest upgrade to the present suite of T/C recorders to will include an additional T/C recorder coupled with a fluorometer and transmissometer. In the near future, we anticipate expanding the suite of sensors to include automated chemical sensors capable of collecting time series of nitrate, acoustical sensors that can detect zooplankton and fish, and other bio-optical sensors useful in quantifying primary production. Many of these techniques are being tested now or under development. We plan to await the outcome of these tests before incorporating such instrumentation on the GAK 1 mooring. The mooring is also available for the deployment of instruments of interest to other users as a community service. For example, this year we have incorporated prototype halibut tags, under development by USGS-BRD scientists, onto the mooring. The mooring could also serve as a platform for passive acoustic recordings of marine mammals and/or ambient environmental noise. The latter could become a future issue in this region as recreational and commercial boat traffic increases.

To guide our immediate efforts we formulated several project-specific objectives, several of which are continuing as discussed in our annual reports (Weingartner, 1999; 2000, 2001). These are:

1. 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, which are not resolved by monthly sampling, reflect important changes whose timing could be significant to the ecosystem. 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.
2. Determine the basic statistical properties of the moored data and how variances in temperature, salinity, and dynamic height are distributed over depth and seasonally. 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.
3. Determine the timing of the onset of stratification in the upper ocean in spring and its relation to the onset of the spring bloom.

B. Methods

Funds are requested to monitor Gulf of Alaska temperature and salinity through FY 02. We propose to collect data at GAK 1 in two ways: monthly CTD profiles throughout the water column and hourly measurements of temperature and salinity at selected depths. Seven times a year (March, April, May, July, August, October, and December) these measurements will be made from the *R/V Alpha Helix* while this vessel is supporting the GLOBEC program. In the remaining months we will use the Institute of Marine Science's 25-foot *Little Dipper* and collect CTD profiles with 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 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 (or during one of the GLOBEC cruises time permitting). Throughout the first four years of this program we have deployed six instruments collecting at nominal depths of 30, 50, 100, 150, 200, and 250 meters. We propose to add a seventh instrument at 10 m depth, to collect temperature, salinity, fluorescence and transmissivity data in the near-surface layer throughout the year. (The instrument is a SeaCat, SBE-16 and is similar to a MicroCat except that it can mate with additional sensors, e.g., the optical sensors). There are several reasons for the proposed addition. First, in conjunction with the instrument at 30 m depth, the instrument at 10 m depth will allow us to assess the seasonal development of stratification in the upper ocean. Second, near-surface temperatures might be very useful in understanding salmon recruitment based upon the work of Willette et al. (1999) since the juvenile fish occupy the upper 10 m of the water column while on the shelf (Boldt and Haldorson, 2000). Third, the addition of the fluorometer and transmissometer will allow us to determine the timing of the spring bloom (based on fluorescence) and its relationship to the development of upper ocean stratification and seasonal changes in suspended sediment load (transmissivity). With the proposed change the instrument distribution covers the near-surface (10 - 30 m), the upper ocean (30–100 m), mid-depth (150–200 m) and bottom (200–250 m) of the water column. While results from the first year indicate that mooring motion is unimportant, we monitor this with a pressure sensor on the uppermost (10 m depth) SeaCat. Our prior experience with these and similar instruments (SeaCats) indicate that temperature and salinity drifts are generally <0.02°C and <0.03 psu/year, respectively.

The analyses of the data sets are straightforward.

Objective 1 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 2 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 according to the proportion of the total system variance that each comprise. Thus 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 3 will be achieved by examining the fluorometer and transmissometer record in conjunction with the density differences determined using the instruments at 10 and 30 m depth. Our analysis will also use the weather data collected by the NOAA meteorological installation at Pilot Rocks, about 20 km south of GAK 1. This weather station is representative of wind and air temperatures on the inner shelf and the data are available over the Internet.

SCHEDULE

A. Measurable Project Tasks for FY 02 (October 1, 2001 – March 30, 2003)

October 15, 2001:	Monthly CTD surveys scheduled at mid-month; update homepage as CTD data are processed and edited; prepare wind fields and acquire meteorological fields.
November–December 2001:	Deploy mooring (the mooring will be deployed as soon as instruments can be delivered from the manufacturer) during this month's CTD sampling.
September 2002:	Recover mooring, send instruments for post-calibrations, begin data processing.
March 2003:	A report will be prepared by the end of March.

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 about 4 months after collection. The final edited temperature and salinity data from the mooring should be ready within five months after instrument recovery. The delays arise because of post-calibration procedures (performed by the manufacturer) and data editing requirements (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, data will not be released if there are severe concerns regarding its quality unless and until such concerns are resolved. In addition to these general considerations, we anticipate the following project milestones:

1. The first 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 4 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.

2. The second objective pertains to basic statistical results and provides the modal description of system variance. The results will be made available in both preliminary and final fashion. These calculations are straightforward and the results and preliminary interpretations would be made available within two months of mooring recovery. When the final data product is ready, we will update the GAK1 CTD homepage describing these statistics and their relevance to historical GAK1 data.

C. Completion Date

This project will be completed by March 2003.

PUBLICATIONS AND REPORTS

No manuscripts will be submitted in FY 02. Data and results will be provided via Internet as indicated above.

PROFESSIONAL CONFERENCES

We have presented some of our prior findings at national conferences in conjunction with our GLOBEC work. In the past year this has included annual EVOS workshop as well as the Ocean Sciences meeting (January 2000, San Antonio) and the Eastern Pacific Ocean Conference (EPOC; September 2000, Sidney, British Columbia). In each case we have melded the GAK 1 results with GLOBEC results where appropriate and have acknowledged the support of EVOS as well as NSF and NOAA. I anticipate that we will continue to do the same in the future. However, I am not seeking funds from EVOS for travel and attendance at the national meetings, as I will use GLOBEC funds to cover these costs.

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 scientists are co-investigators on a GLOBEC proposal whose results would complement this proposal. The UAF investigators (Coyle, Hopcroft, 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 2000 –December 2004. This work includes seven 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. Costs for the GAK 1 data collection are shared with the GLOBEC program insofar as seven of the monthly cruises to GAK 1 will be undertaken by GLOBEC. Thus we are requesting support for only five *Little Dipper* cruises. Further, Hopcroft's GLOBEC work includes estimating zooplankton growth rates and production based on changes in zooplankton age-frequency composition at GAK 1. He will conduct several *Little Dipper* cruises during the year in addition to those described above. He will also collect CTD profiles as well during his cruises (following the same procedures as discussed above); thereby increasing the number of profiles available to this project. Other GLOBEC investigators (Strom, Western Washington; Dagg; Louisiana State; Napp, NOAA) will be investigating zooplankton dynamics in 2001 and

2003 in the northern Gulf of Alaska and we anticipate that the GAK 1 data will be of use to them as well. Finally, NOAA-PMEL will deploy several moorings over the middle and outer shelf south of GAK 1 (along the Seward Line). Data from these in conjunction with the GAK 1 data set should provide a better understanding of synoptic and seasonal changes over this shelf. Finally, the long-term ARGO program will begin deploying ALACE floats (CTD profiling drifters) in the Gulf of Alaska basin (H. Freeland, Institute of Ocean Sciences, Sydney, BC) this year. The GAK 1 monitoring and the ARGO program will eventually afford a better understanding of how climate variability affects this shelf and basin.

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 (~90 at the conclusion 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 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.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

We propose to add 1 SeaCat, SBE-16 to the mooring at a depth of 10 m. It will contain a fluorometer, transmissometer and pressure gauge to monitor diving. The reasons for the proposed addition are: 1) to begin to assess the interannual variation in the seasonal development of stratification and timing of the spring bloom over the inner shelf and 2) because near-surface temperatures might be useful in understanding juvenile salmon survival (Willette et al., 1999) since these fish inhabit the upper 10 m of the water column on the shelf (Boldt and Haldorson, 2000).

PROPOSED PRINCIPAL INVESTIGATOR

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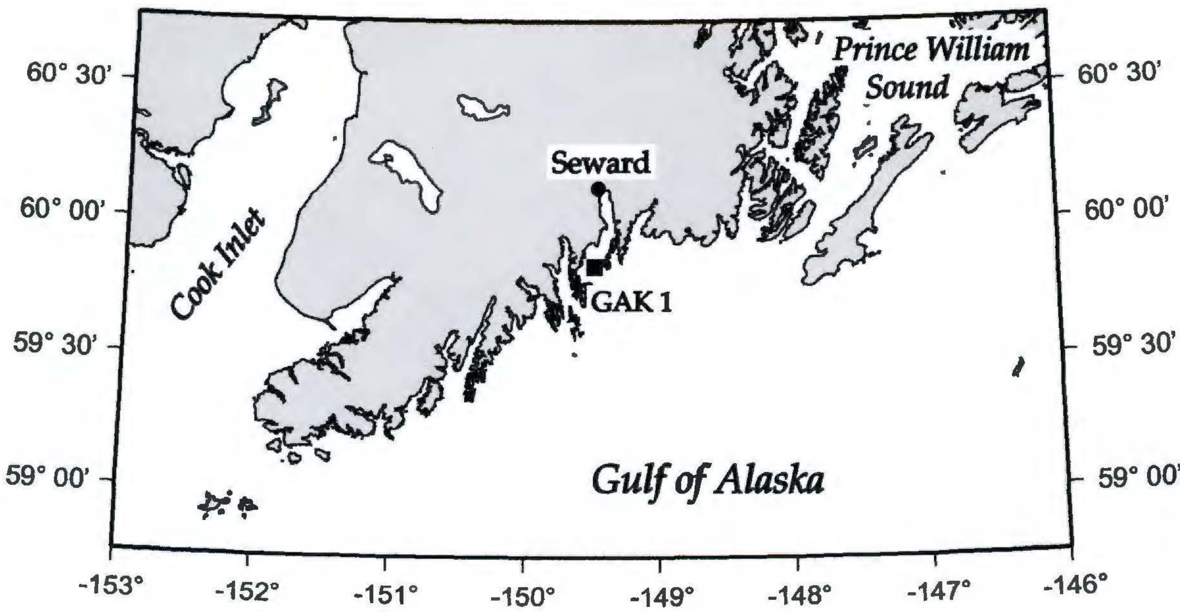

Figure 1. Map showing location of hydrographic station GAK1 in relation to Prince William Sound, Cook Inlet and Seward.

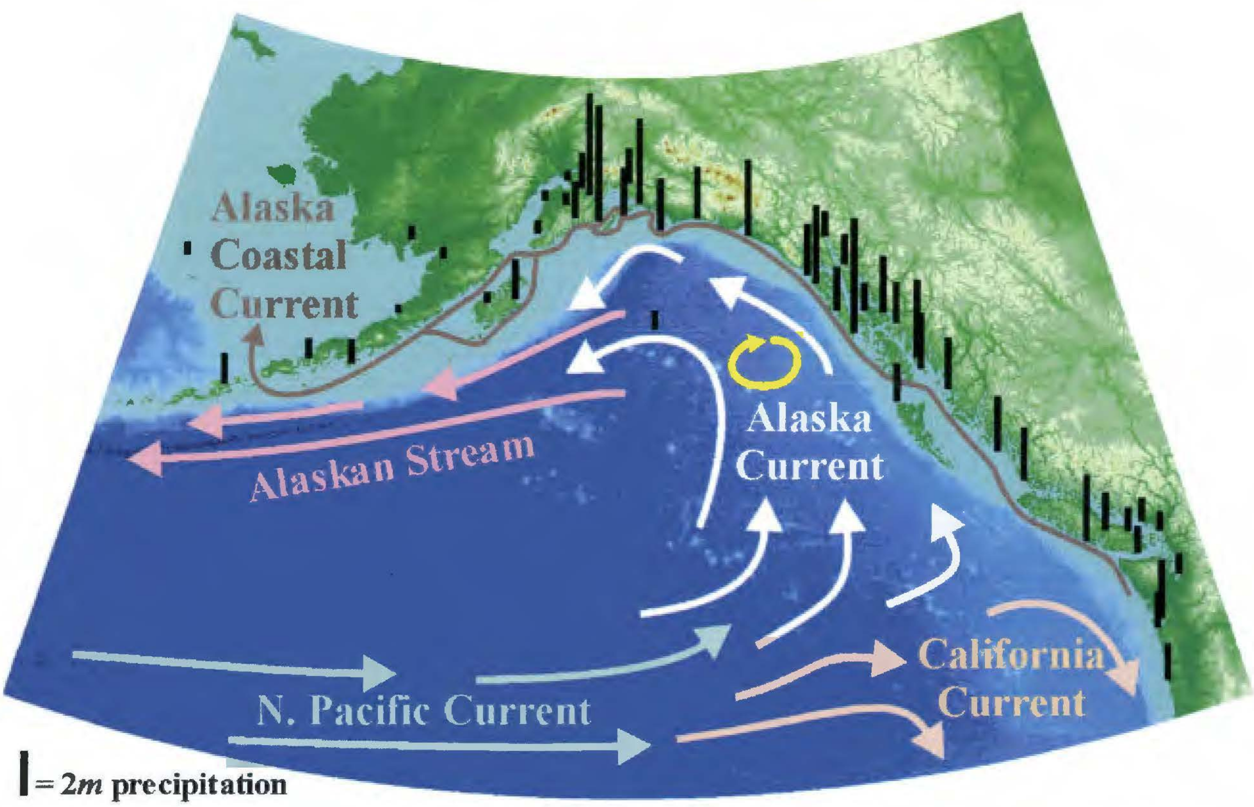

Figure 2. Schematic of the circulation of the Northeast Pacific and Gulf of Alaska. The vertical bars are the mean annual precipitation amounts at selected National Weather Service coastal sites and in the interior of the Gulf of Alaska. The latter is from Baumgartner and Reichel (1975).

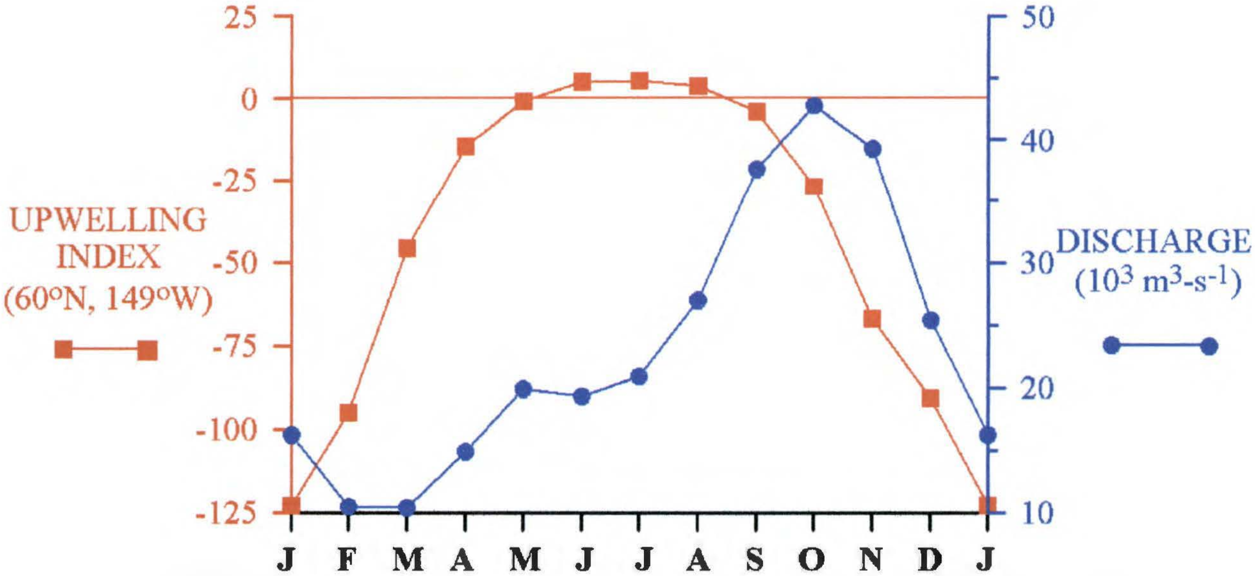

Figure 3. Mean monthly values of the upwelling index (from 1946–1995) and the estimated freshwater discharge (from 1930–1992) into the Gulf of Alaska using the hydrology model of Royer (1982).

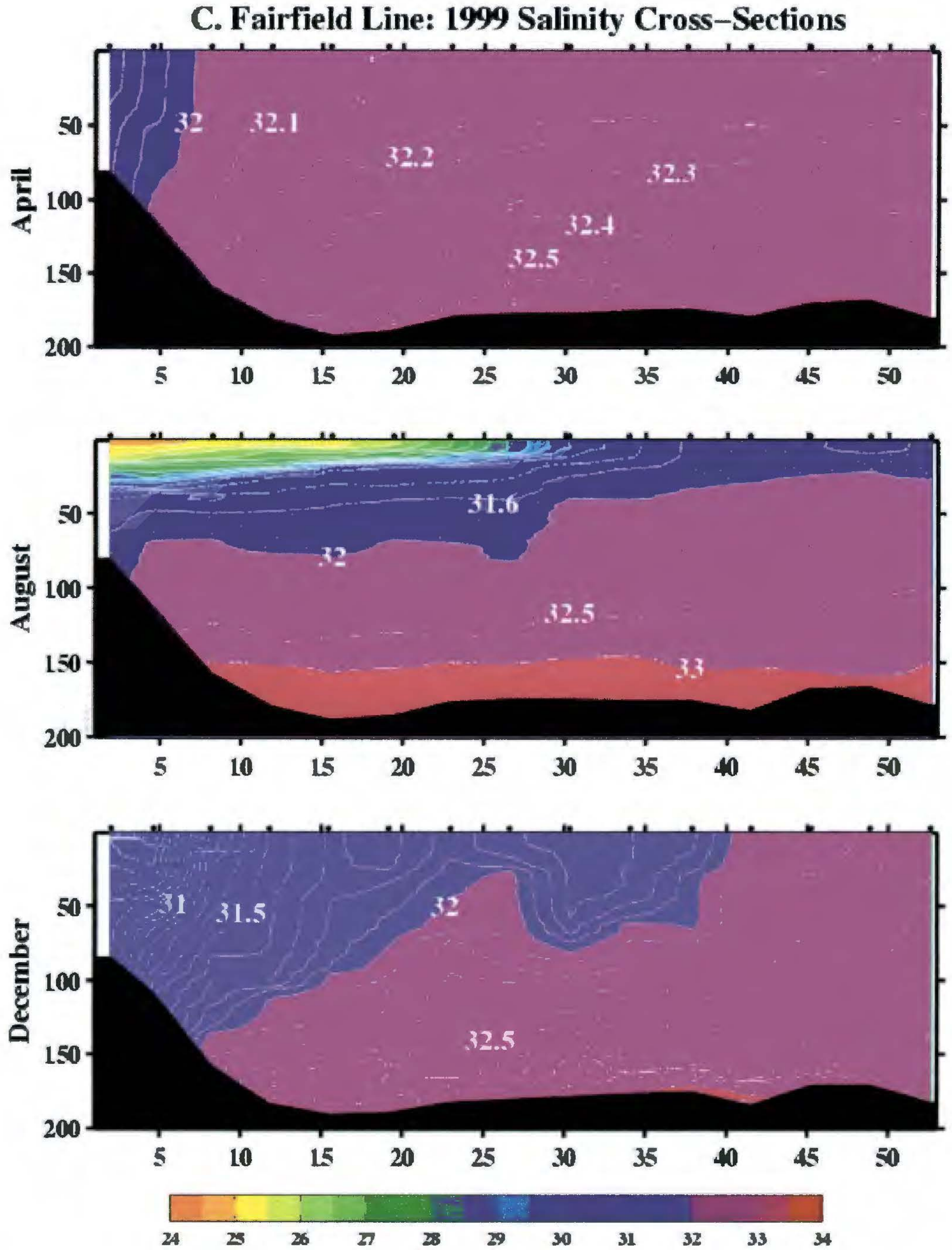

Figure 4. Contours of salinity as a function of depth and cross-shore distance for April, August and December 1999. The data were collected along a transect near Cape Fairfield (north on the left) in the northern Gulf of Alaska and approximately 30 km east of GAK 1.

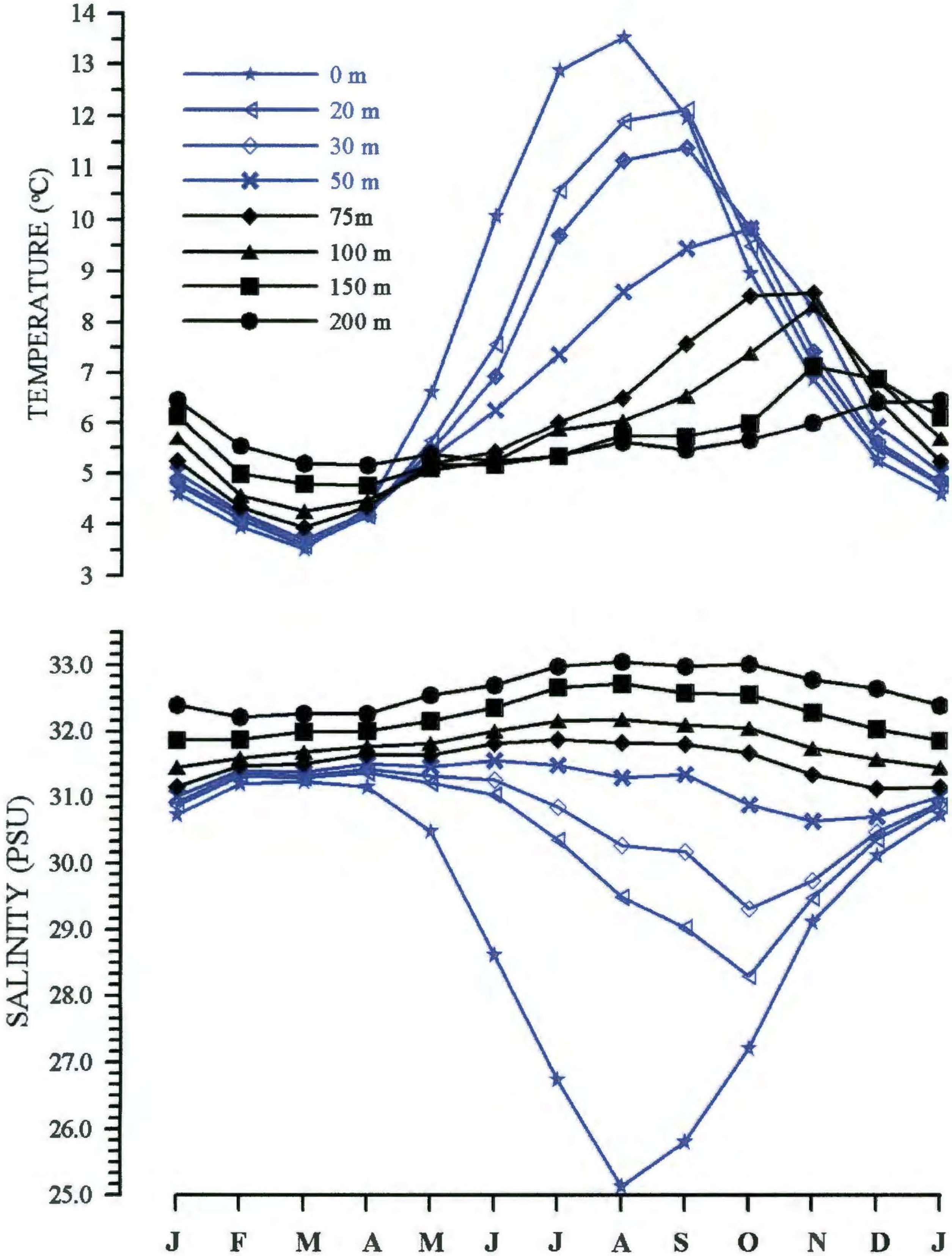

Figure 5. Mean monthly temperature (upper) and salinity (lower) at GAK1 as a function of depth. The means are computed from data collected between 1970 and 1999.

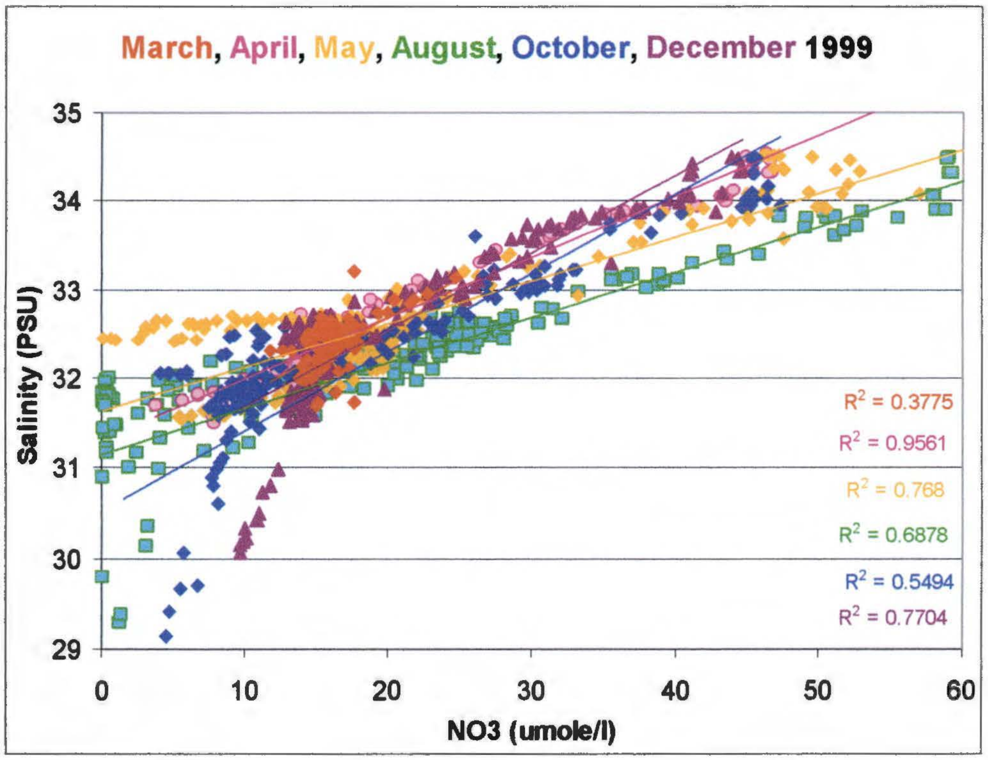

Figure 6. NO_3–salinity scatter plot from the shelf and slope of the northwest Gulf of Alaska (from Childers, pers. comm.).

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

PROFESSIONAL EXPERIENCE

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

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

OTHER KEY PERSONNEL

Mr. David Leech is the Seward based mooring and marine technician responsible for the design and deployment of the mooring. He will also conduct the monthly CTD sampling from the *Little Dipper*. Mr. Seth Danielson is the computer programmer who will assist in data processing, analyses, and maintenance of the web page. Both are employees of the Institute of Marine Science.

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2002 *EXXON VALDEZ* TRU[illegible] COUNCIL PROJECT BUDGET

October 1, 20[illegible] - [illegible]eptember 30, 2002

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$0.0						
Travel		$0.0						
Contractual		$55.9						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$55.9	Estimated FY 2003					
General Administration		$3.9						
Project Total		$59.8	$15.5					
Full-time Equivalents (FTE)		0.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY02

Prepared:

Project Number: 02609
Project Title: Long-Term Temperature/Salinity Monitoring Within the Alaska Coastal Current
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Budget Category:	Authorized FY 2001	Proposed FY 2002						
Personnel		$18.7						
Travel		$0.5						
Contractual		$7.5						
Commodities		$3.1						
Equipment		$15.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$44.8	Estimated FY 2003					
Indirect		$11.1						
Project Total		$55.9	$14.5					
Full-time Equivalents (FTE)		0.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

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

FY02

Prepared:

Project Number: 02609
Project Title: Long-Term Temperature/Salinity Monitoring Within the Alaska Coastal Current
Name: Thomas J. Weingartner

FORM 4A
Non-Trustee
SUMMARY

Personnel Costs:			Months	Monthly		Proposed
Name	Position Description		Budgeted	Costs	Overtime	FY 2002
Weingartner, T.	PI/Associate Professor		0.5	6.8		3.4
Danielson, S.	Analyst Programmer		0.8	5.6		4.2
Leech, D.	Technician		1.8	5.4	1.7	11.1
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		3.1	17.8	1.7	
					Personnel Total	$18.7

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2002
Fairbanks to Anchorage	258.0	1	2	121.0	0.5
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$0.5

FY02

Prepared:

Project Number: 02609
Project Title: Long-Term Temperature/Salinity Monitoring Within the Alaska Coastal Current
Name: Thomas J. Weingartner

FORM 4B
Personnel
& Travel
DETAIL

2002 *EXXON VALDEZ* TRU COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

Contractual Costs:	Proposed
Description	FY 2002
Little Dipper: 2 half days @ $208/half day (Jun, Sep)	0.4
Little Dipper: 3 days @ $416/day (Jan, Feb, Nov)	1.3
CTD calibration	0.6
Microcat calibration (7 @ $600 ea.)	4.2
Shipping (R/T Seward-Seattle: CTD and Micri/cats	1.0
Contractual Total	$7.5

Commodities Costs:	Proposed
Description	FY 2002
Batteries, O-rings, vane assembly parts	2.0
Shackles, sling links, thimbles	0.5
Standard seawater (5 @ $30/vial)	0.2
Mooring anchor and lashing chain	0.4
Commodities Total	$3.1

FY02

Prepared:

Project Number: 02609
Project Title: Long-Term Temperature/Salinity Monitoring Within the Alaska Coastal Current
Name: Thomas J. Weingartner

FORM 4B
Contractual &
Commodities
DETAIL

2002 *EXXON VALDEZ* TRU E COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2002
1 SeaCat with transmissometer, fluorometer and pressure gauge			15.0
			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**	$15.0

Existing Equipment Usage: Description	Number of Units	

FY02

Prepared:

Project Number: 02609
Project Title: Long-Term Temperature/Salinity Monitoring Within the Alaska Coastal Current
Name: Thomas J. Weingartner

FORM 4B
Equipment
DETAIL