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

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| Project Number: | 00340 |
| Restoration Category: | Monitoring |
| Proposer: | University of Alaska Fairbanks |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | none |
| Alaska SeaLife Center: | no |
| Duration: | 3nd year, 4-year project |
| Cost FY 00: | $64,828 |
| Cost FY 01: | $67,321 |
| Geographic Area: | Resurrection Bay/Gulf of Alaska shelf |
| Injured Resource/Service: | All organisms and services |



## ABSTRACT

Interannual variations in the temperature and salinity of Gulf of Alaska shelf waters could significantly influence this ecosystem and, therefore, the recovery and restoration of organisms and services affected by the *Exxon Valdez* oil spill. This variability is best quantified from long time series such as that gathered over 28-years at a hydrographic station (GAK1) near Seward. This program will continue this time series to quantify variability on this shelf. First year results suggest that sea level might be an effective monitor of upper ocean summer salinity. The temperature-salinity correlation structure suggests causative mechanisms that will be explored as part of this program. The data and the analyses will aid in designing a cost-effective monitoring program.

## INTRODUCTION

This is a continuation proposal describing the third of a proposed four-year effort to maintain the existing 29-year time series of conductivity-temperature versus depth (CTD) data collected at hydrographic station GAK1. Funding from EVOS for these measurements began in November 1997 with monthly cruises to station GAK1. These are continuing through September 1999. 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) gives a more complete description and analysis of the data collected thus far. However, the findings thus far indicate:

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) 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 beginning May 1998 and continuing.
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. Monthly temperature and salinity anomalies are negatively correlated in the upper 100 m of the water column leading to the hypothesis that anomalously warm summers are abnormally fresh and anomalously cold winters are abnormally salty.
8. The sea level rise between May and September at Seward, Alaska, is primarily a function of salinity decrease in the upper 50 m of the water column. We hypothesize that sea level records at Seward (and possibly other coastal locations around Alaska) could be used to assess precipitation and runoff anomalies around the Gulf of Alaska where measurements of discharge and precipitation are sparse.

This program will continue the measurements at GAK1 but also will begin a more extensive analysis of the existing data sets. A particular focus will be on the data-driven hypotheses listed in items 6 and 7 above.

The GAK1 environmental data are representative of conditions in the northern Gulf of Alaska and the Bering Sea (Royer, 1993) and are being used to assess the role of environmental variability in the ecology of fisheries and marine mammals in these regions. Station GAK1 lies

in 260 m of water at the mouth of Resurrection Bay, midway between Prince William Sound and Cook Inlet (Figure 1). GAK1 data should be helpful in placing many of the restoration studies sponsored by the Trustee Council in the context of interannual and interdecadal hydrographic variability. These data complement the goals of the Gulf of Alaska component of the U.S. Global Ocean Ecosystem Dynamics program (GLOBEC), which began in October 1997. GLOBEC is supported by the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA). It consists of three components: monitoring, process studies, and modeling. Monitoring began in the Gulf of Alaska in October 1997, with modeling and process studies to follow in 2001. The proposal described here will encourage synthesis of the ecosystem studies supported by the Trustee Council and GLOBEC. In the following paragraphs we summarize the regional oceanography and the historical data from GAK1. This background information provides the context for understanding the rationale and the design of the project described in subsequent sections.

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

The Alaska Coastal Current is the most striking shelf circulation feature in the Gulf, and station GAK1 is positioned along its inshore edge. The main axis of this swift (0.2–1.8 m $s^{-1}$) westward-flowing current is within 35 km of the coast (Royer, 1981; Johnson et al., 1988; Stabeno et al., 1995). The coastal current is a perennial feature that circumscribes the Gulf of Alaska shelf for some 2500 km (at a minimum) from its origin on the northern British Columbia shelf (or possibly even the Columbia River depending on the season) to where it enters the Bering Sea in the western Gulf. The current is intimately connected to Prince William Sound, feeding the Sound through Hinchinbrook Entrance and draining it primarily through Montague Strait and the westernmost passes (Niebauer et al., 1994). It is also the source of shelf waters for Cook Inlet and transports inlet waters southwestward through Shelikof Strait (Muench et al., 1981). The Alaska Coastal Current transported much of the oil spilled by the *Exxon Valdez* along the south and west coasts of Alaska (Royer et al., 1990).

The dynamics of the Gulf of Alaska shelf are closely coupled to the Aleutian Low atmospheric pressure system. Storms propagate eastward into the Gulf and are blocked by the mountain ranges of Alaska and British Columbia. Consequently, regional winds are strong and cyclonic and precipitation rates are very high. On the shelf, these winds impel an onshore surface Ekman drift and establish a cross-shore pressure gradient that forces the Alaska Coastal Current. The high rates of precipitation, up to 8 m $yr^{-1}$, cause an enormous freshwater flux (~20 % larger than the average Mississippi River discharge) that feeds the shelf as a "coastal line source" extending from Southeast Alaska to Kodiak Island (Royer, 1982). The seasonal variability in winds and freshwater discharge (Figure 2) is large. (Winds are represented in Figure 2 as the upwelling index, a measure of the strength of cyclonic wind stress in the Gulf. Negative values mean coastal convergence and downwelling while positive values signify coastal divergence and upwelling. With respect to Alaska's south coast, negative values imply winds blowing to the

west and positive values imply that the winds blow to the east.) The mean monthly "upwelling index" at locations on the Gulf of Alaska shelf is negative in most months, indicating the prevalence of coastal convergence. Cyclonic winds are strongest from November through March and feeble or even weakly anticyclonic in summer when the Aleutian Low is displaced by the North Pacific High (Royer, 1975; Wilson and Overland, 1986). The seasonal runoff cycle (Figure 2) exhibits slightly different phasing from the winds: it is maximum in early fall, decreases rapidly through winter when precipitation is stored as snow, and attains a secondary maximum in spring due to snowmelt (Royer, 1982).

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

Both of Royer's results suggest that there might be a relationship between monthly (and perhaps shorter period) *cross-shelf dynamic height (or upper ocean density) gradients* and winds and/or freshwater discharge. Conceivably, the monthly anomalies of these variables are also correlated. If firm relationships among these parameters can be established, then the alongshelf (baroclinic) transport might be gauged from a conveniently located (e.g., GAK1) hydrographic station or mooring. Freshwater discharge (Royer, 1982) and winds (Livingstone and Royer; 1980) are coherent over a broad along shore distance. Integral time scales of temperature and salinity (calculated from the EVOS-supported mooring at GAK1, Weingartner, 1999), are about 1 month on this highly advective shelf and therefore suggesting that the variables have broad along shore coherence. One implication of this finding is that a single measuring site is representative of a broad along shore region of the shelf. These findings are enormously useful for model evaluation (and data assimilation), retrospective studies, and monitoring.

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

migratory corridor for numerous species of marine mammals (Calkins, 1986) and sea birds (DeGange and Sanger, 1986).

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

The oceanographic description sketched above stems from research that began in 1970. Beginning that year research vessels from the University of Alaska and other organizations opportunistically sampled station GAK1 while in transit to and from the Seward Marine Center. This ad hoc sampling, conducted at nominally monthly intervals, was the beginning of what is now a 29-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 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. Other EVOS investigators have showed that warm ocean temperatures enhance survival of young-of-the-year salmon (Willette et al., 1999) and overwintering herring (Norcross et al., 1999). Conceivably then, the GAK1 record could eventually be incorporated into management decisions.

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

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

In summary, several data sets now suggest that the Gulf of Alaska ecosystem is sensitive to environmental variations on time scales ranging from interannual to interdecadal. Other data sets suggest possible biophysical linkages that cause these ecological responses. However, we lack an adequate characterization of shorter period (seasonal to synoptic) variations that might impinge on the biological components of this ecosystem. Moreover, a mechanistic understanding of the physical dynamics of the Gulf of Alaska shelf and the processes linking environmental variability to ecosystem alterations is lacking. These are complex problems that require a concerted and interdisciplinary approach involving process-specific studies in addition to ecosystem monitoring. Some of these programs (APEX and SEA) are sponsored by the Trustee Council, while a new initiative, the U.S. Global Ocean Ecosystem Dynamics program, began in the fall of 1997 on the Gulf of Alaska shelf. The GLOBEC program is specifically designed to elucidate details of the mechanisms underlying physical and biological environmental change on

the shelf. For example, the nutrient cycles and concentrations on the Gulf of Alaska shelf are poorly understood at present (Reeburgh and Kipphut, 1986) but will be investigated in the GLOBEC program. Those results should benefit the monitoring proposed herein. In tandem, the GLOBEC- and Trustee-supported efforts will lead to improvements in ecosystem monitoring.

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

## NEED FOR THE PROJECT

### A. Statement of Problem

The GAK1 monthly time series portrays the very large interannual and interdecadal variability of the high latitude North Pacific. With a greater sampling rate, shorter period variations can be detected, revealing any temporal aliasing problems. The results will enhance interpretations of the historical data and place the magnitude of previous anomalies in a better statistical framework. Moreover, the time series could serve as a proxy for transport in the Alaska Coastal Current. Variability in the marine environment, as reflected in ocean temperatures and salinities, and, if possible, shelf circulation, need to be quantified to understand the structure of, and changes in, the northern Gulf of Alaska marine ecosystem. Such changes might influence the recovery of many of the marine species and marine services listed in Table 4 of the Proposal Invitation. 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 who need information on environmental variability. The information will help assess recovery and restoration progress by allowing these issues to be analyzed within the context of the long-term variability of the physical environment. The GAK1 data set provides some of that information and the proposed measurements will enable continuation of these efforts by collecting time series at GAK1 of:

1. Monthly temperature and salinity at every meter throughout the water column using a conductivity–temperature–depth (CTD) instrument.

2. Hourly temperature and salinity at several fixed depths distributed throughout the water column.

This information will assist in:

1. Understanding thermohaline variability on time scales ranging from the tidal to the interdecadal.

2. Interpreting historical data sets for use in retrospective studies.

3. Configuring a cost-effective, long-term monitoring program.

4. Designing process studies necessary to develop ecosystem models for this shelf.

### C. Location

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

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

We do not see any overt connection to traditional ecological knowledge. However, the most expedient way to share these data with both the public and scientific communities is via the internet. Such a link will allow easy access to the data for those working at the community level and with traditional ecological knowledge. We have recently learned that the Alaska Department of Environmental Conservation (ADEC) maintains a VHF radio repeater on Rugged Island and within 1.5 miles of GAK1. The ADEC has indicated that the repeater station could be shared with other users. If technical obstacles can be overcome, we will seek to upgrade GAK1 so that data collected from this mooring could be transmitted, via VHF signal, in near real time directly into Seward (preferably the Alaska SeaLife Center) for immediate use and display. A VHF transmission would be considerably cheaper than data links via ARGOS or Iridium (cell phone).

## PROJECT DESIGN

### A. Objectives

Two objectives motivate this multi-year program. First, we want to continue the 29-year time series at station GAK1 through a combination of monthly CTD measurements and through year-long deployments of a mooring containing temperature and conductivity (T/C) recorders.

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. We recognize that our generic goal of ecosystem monitoring is a long-term undertaking requiring incremental efforts and so view our efforts as essential steps toward that goal. To guide our efforts we formulated several project-specific objectives, several of which are underway, and discussed them in the first year's annual report (Weingartner, 1999). 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 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. The sea level rise between May and September at Seward, Alaska, is primarily a function of salinity decrease in the upper 50 m of the water column. Determine if the sea level record at Seward could be used to assess freshwater discharge anomalies around the Gulf of Alaska. If such a relation can be constructed then the historical sea level record from Seward can be used to examine anomalies in coastal discharge. As results evolve, we will incorporate them into the website.
4. Investigate the hypothesis that anomalously warm summers are abnormally fresh and anomalously cold winters are abnormally salty. As results evolve, we will incorporate them into the website.

All objectives rely on continued sampling at GAK1. The last two objectives represent exploratory studies of the GAK1 data set would be valuable for retrospective analyses.

**B. Methods**

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

We propose to collect data monthly with the Institute of Marine Science's 25-foot *Little Dipper* using a Seabird SBE-25 internally-recording CTD deployed from the vessel's winch. The sensors on this CTD are calibrated annually by the manufacturer. Field checks on the conductivity sensor

are made from bottle salinities collected during each cast and analyzed on the salinometer at the Seward Marine Center. This procedure allows detection of CTD drift between calibrations by the manufacturer. The historical salinity data have an accuracy of ~0.01 or better using this instrument and these procedures. Temperatures are accurate to within 0.005°C.

The monthly sampling will be complemented by hourly measurements from six temperature/conductivity recorders (Seabird MicroCats; SBE model 37-SM) incorporated in a taut-wire, subsurface mooring at GAK1. The mooring can be deployed and recovered by the *Little Dipper* during the CTD cruises. The instruments will make hourly measurements at nominal depths of 30, 50, 100, 150, 200, and 250 meters. This distribution covers the near-surface (30 m), the upper ocean (30–100 m), mid-depth (150–200 m) and bottom (200–250 m) of the water column. (Although observations at the surface would be useful, obtaining these would entail a mooring with substantially higher hardware and fabrication costs and the need for a larger vessel for servicing.) While results from the first year indicate that mooring motion is unimportant, this is monitored with a pressure on the MicroCat at 30-m depth. Our prior experience with these and similar instruments (SeaCats) indicate that temperature and salinity drifts are generally <0.01°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 by the proportion of the total system variance that each composes; the first mode accounts for the greatest fraction of system variance and the sixth mode accounts for the smallest proportion. Often, only a few modes are required to describe the system variance, and the significance of a given mode will be assessed following Overland and Preisendorfer (1982). The spatial structure of a mode describes the distribution of amplitude with depth, while its temporal structure describes how the mode varies through time. The EOFs are useful in consolidating large and complicated data sets into smaller correlated subsets that facilitate physical interpretation. They might also contribute to future monitoring design by suggesting times and/or depths that are either over- or under-sampled. In the latter case, the EOFs could identify potential temporal or spatial aliasing problems.

Objective 3 will correlate winds and upper ocean density (dynamic height) with Seward sea level. This motivation follows from Royer's (1979) observation of a statistically significant relationship between monthly dynamic height and Seward sea level. His findings suggest that a time series of sea level and/or dynamic height at a single location might provide an index of

transport variability in the Alaska Coastal Current. To firmly establish the relationship between coastal transport and sea level will require making direct current measurements in the coastal current and comparing these with sea level. While such measurements are beyond the scope of this proposal, detection of significant relationships would provide compelling support to undertake a more ambitious transport measurement program. We regard this last objective as a feasibility study that will relate sea-level fluctuations to the two dominant forcing mechanisms for the shelf circulation: freshwater (which affects upper ocean density) and alongshore winds. The statistical analyses will entail multivariate spectral techniques (Groves and Hannon, 1968; Bendat and Piersol, 1971) to examine the multiple and partial coherences among the independent (winds and dynamic height) and dependent (sea-level) variables. This technique, analogous to partial and multiple correlation, identifies statistically significant relationships among these variables as a function of frequency (time period). Estimates of dynamic height using the MicroCats will depend upon the numerical technique used to perform the vertical integrations. The choice will be guided by comparisons of dynamic height with high resolution CTD data and consideration of EOF results.

Objective 4 involves exploring the covariance structure of the monthly temperature and salinity anomalies at GAK1. We will apply singular value decomposition (SVD) to these data (and possibly other data sets also) which will yield spatial and temporal patterns that tend to occur simultaneously with one another (see Preisendorfer, 1988, for a thorough discussion of the technique). Weingartner (1999) suggested a simple atmospherically driven hypothesis to explain the strong inverse correlation between temperature and salinity in the upper 100 m at GAK1. In winters when the ocean temperature is low and salinity high, the atmosphere contains relatively low moisture, precipitation is stored as snow in the coastal mountain ranges, and the ocean to atmosphere heat loss is large. In winters when the ocean temperature is high and salinity low, the atmosphere contains more moisture, rainfall is heavy along the Alaskan coast, and the ocean to atmosphere heat loss is small. Cold summers result in reduced snowmelt, higher salinities, reduced solar radiation, and possibly greater vertical mixing. Warm summers result in high runoff, lowered surface salinities, reduced winds and higher net solar radiation. We will explore these potential mechanisms using the temporal modes from the SVD as a guide. The GAK1 data and analyses will be supplemented by other data sources, including various monthly atmospheric fields (air pressures, atmospheric moisture, temperatures, and winds) prepared by the National Center for Atmospheric Research. The results should lead to new insights on mechanisms responsible for the observed ocean variability in the Gulf of Alaska.

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

**SCHEDULE**

## A. Measurable Project Tasks for FY 00 (October 1, 1999 – September 30, 2000)

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| October 15: | Monthly CTD surveys, scheduled at mid-month; update homepage as CTD data are processed and edited; prepare wind fields and acquire meteordogical fields. |
| November–December: | Deploy mooring (the mooring will be deployed as soon as instruments can be delivered from the manufacturer) during this month's CTD sampling. |
| September: | If FY 01 field monitoring is not funded, then recover mooring, send MicroCats for post-calibrations, begin data processing. Otherwise mooring will be recovered in November or December of 2000 when replacement mooring is deployed. |

## B. Project Milestones and Endpoints

The data collected as part of this project will be available to a broad community of users. We anticipate that some will want "immediate" access to it. This desire often conflicts with the goal (and required time) of producing data of the highest possible quality. In the past, the final CTD data have generally been placed online 1–2 months after collection. The final edited temperature and salinity data from the mooring should be ready three months after instrument recovery. The delays arise because of post-calibration requirements (performed by the manufacturer) and final editing of the data sets (performed at the Institute of Marine Science). We intend to make much of the data, along with preliminary results, available for rapid dissemination. From a practical point of view this approach is prudent because for many users the differences between the raw and the final edited product are insignificant. We will attach appropriate warnings concerning data quality to both preliminary and final data products. Thus, we anticipate making most of the data available on the homepage one month after recovery of the mooring. However, we will not release any data for which there are severe concerns regarding quality unless and until these concerns are resolved. In addition to these general considerations, we anticipate the following project milestones:

1. The first objective pertains to basic statistical results which will be made available in both preliminary and final fashion. When the final data product is ready, we will update the GAK1 CTD homepage describing these statistics and their relevance to historical GAK1 data.

2. The second objective is to examine rates of change of water mass properties (temperature and salinity) and the phasing of these changes at different depths. This work is largely descriptive and will begin immediately after instrument recovery. Graphical data displays will be made available within 1–2 months of recovery. These will include textural information indicating features of interest. Displays will be updated periodically as new findings emerge. Eventually these results will be merged with those of the third objective.

3. The third objective provides the modal description of system variance. These calculations are straightforward and the results and preliminary interpretations would be made available within two months of mooring recovery. Further interpretation will entail more reflection and likely require completion of the last objective.

4. Four months after recovering the mooring, correlations among winds, corrected sea level, and upper ocean density will begin. We will first compare dynamic height determined from CTD data with that from the moorings. Combining these results with those from Objective 3, we will perform the multiple coherence calculations. We estimate that this objective will be completed two months after it is begun.

If the mooring is recovered in September 1999, all objectives will be reached by early April 2000. If the mooring is recovered in November 1999, all objectives will be reached by early June 2000. Similar analyses and schedules will occur for each year of support. Comparison of the results among years will provide additional indications of statistical variability.

### C. Completion Date

This project will be completed in FY 01.

## PUBLICATIONS AND REPORTS

No manuscripts will be submitted in FY 00. Data and results will be provided via internet as indicated above.

## PROFESSIONAL CONFERENCES

Conference presentations will be made in FY 00, probably at a national meeting such as the AGU/ASLO Ocean Sciences meeting in San Antonio, Texas, January 2000.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

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

Several UAF scientists are co-investigators on a GLOBEC proposal whose results would complement this proposal. The UAF investigators (Coyle, Paul, Haldorson, Whitledge, Weingartner) along with Royer (Old Dominion University) have funding from the NSF NOAA GLOBEC program to examine the Gulf of Alaska shelf ecosystem for the period October 1997–December 2000. This work includes six R/V *Alpha Helix* cruises spaced throughout the year to examine the cross-shelf hydrography (including nutrients) and the distribution of phytoplankton, primary production, zooplankton and fish (mainly juvenile salmon and forage fish) in relation to the physical environment.

We see these programs as highly complementary in several ways. First, the cross-shelf hydrography will provide a basis for comparison with variations observed at GAK1. Second, a sufficient number of cross-shelf dynamic height *gradients* (proportional to the ocean transport) would be available (37 over the duration of the GLOBEC program) to examine the correlation between this gradient and dynamic height at GAK1. This result will help determine if dynamic height at a single station can provide an index of transport in the Alaska Coastal Current. Third, a comprehensive nutrient data set will be made available for establishing the type of correlations alluded to in the introduction. If significant correlations are obtained at several depths in the water column, then the GAK1 data would be a proxy indicator of historical variations in nutrient concentrations (for some depths).

The GLOBEC proposal makes connections with other investigators. For example, we have offered berth space on the *Alpha Helix* during our GLOBEC cruises to Robert Day of Alaska Biological Research, Inc., Fairbanks, for his sea bird and marine mammal studies. (Dr. Day is submitting a proposal to the Trustee Council for this project.) Thomas Kline of the Prince William Sound Science Center participated in two GLOBEC cruise and plans to participate in this year's cruises also.

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

**PROPOSED PRINCIPAL INVESTIGATOR**

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Fax: 907-474-7204
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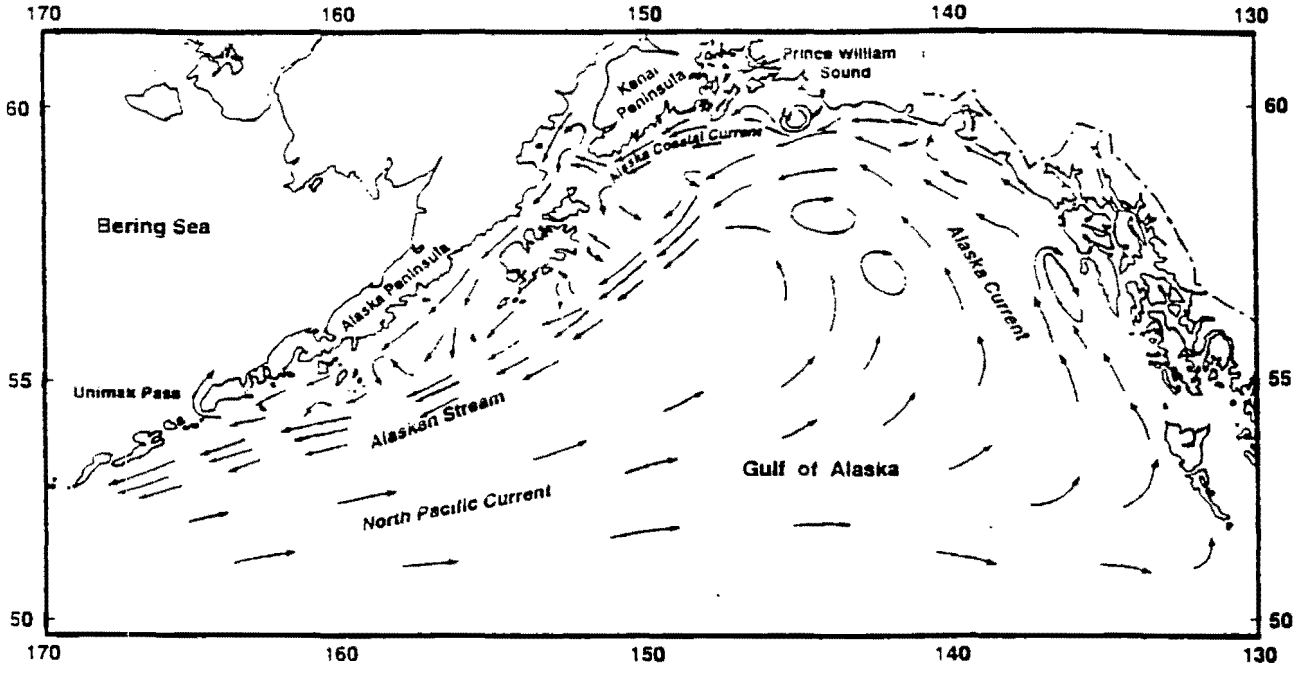


Figure 1. Schematic of the circulation of the Northeast Pacific and Gulf of Alaska (From Reed and Schumaker, 1986).

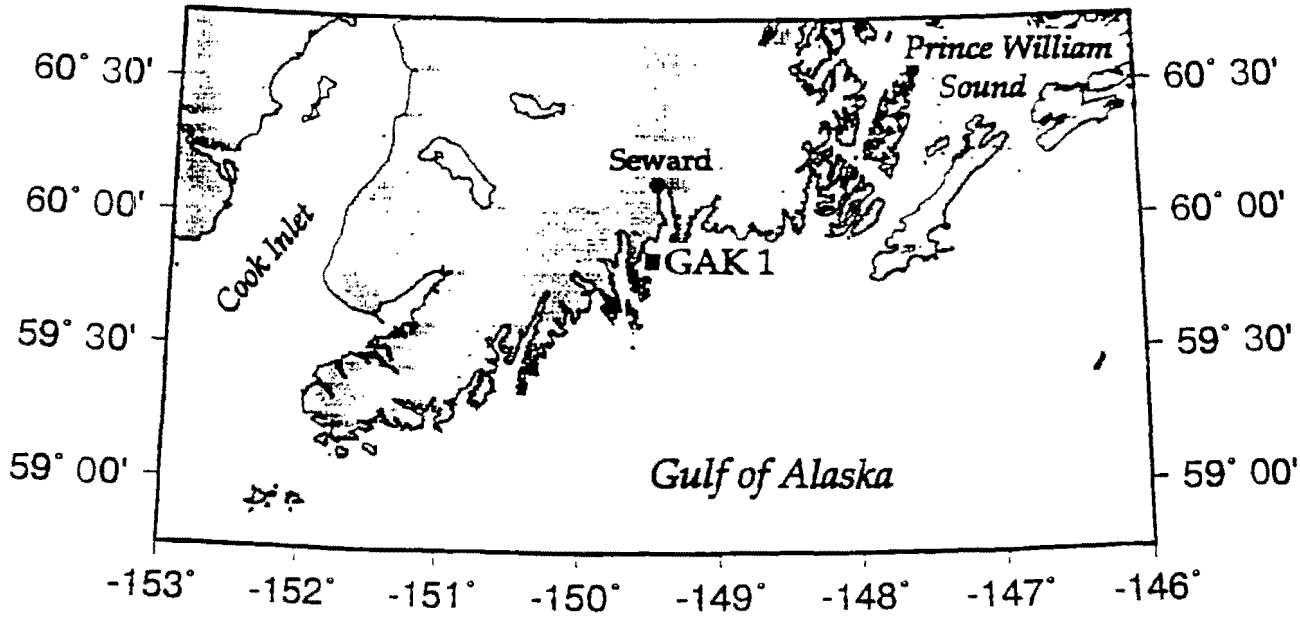


Figure 2. Map showing location of hydrographic station GAK1 in relation to Prince William Sound, Cook Inlet and Seward.

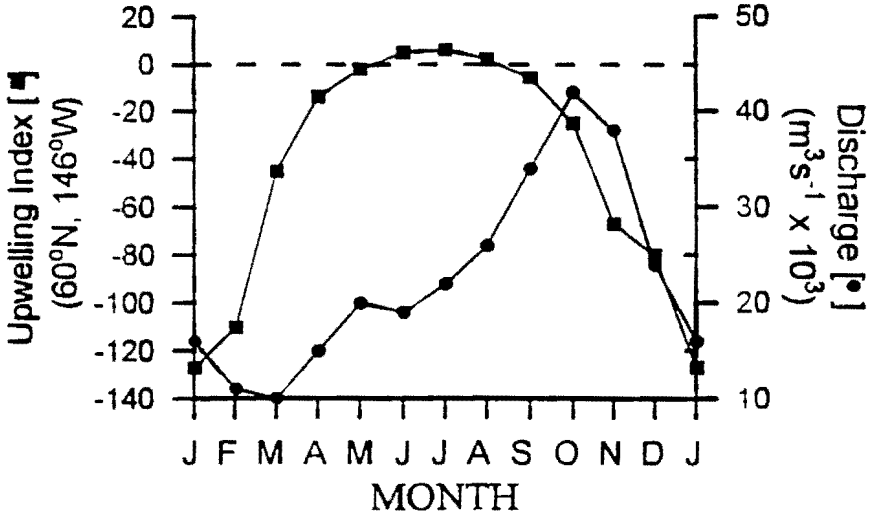


Figure 3. Mean monthly values of the upwelling index (from 1946–1995) and the estimated freshwater discharge (from 1930–1992) into the Gulf of Alaska using the hydrology model of Royer (1982).

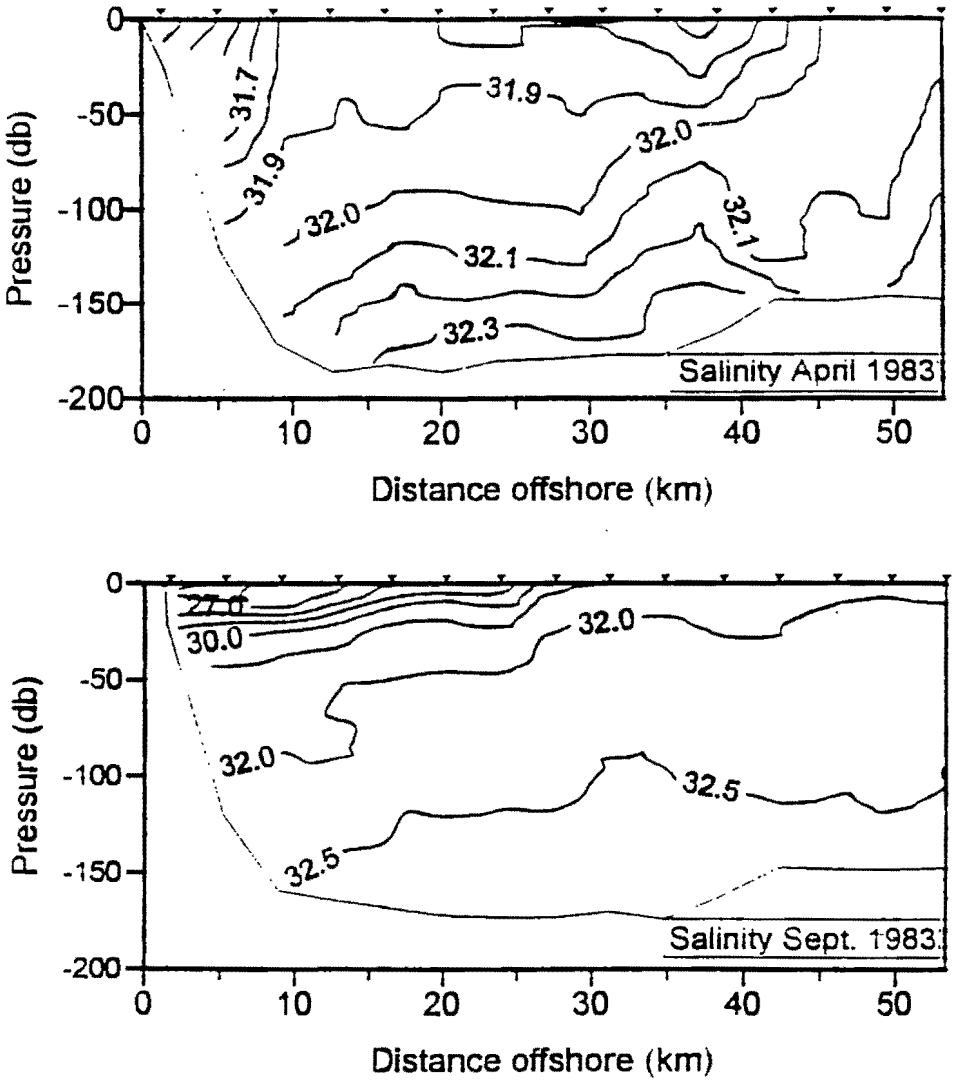


Figure 4. Contours of salinity as a function of depth and position in the Gulf of Alaska on a cross-shelf transect near GAK1. The upper panel is from April 1983 and the lower panel is from September 1993.

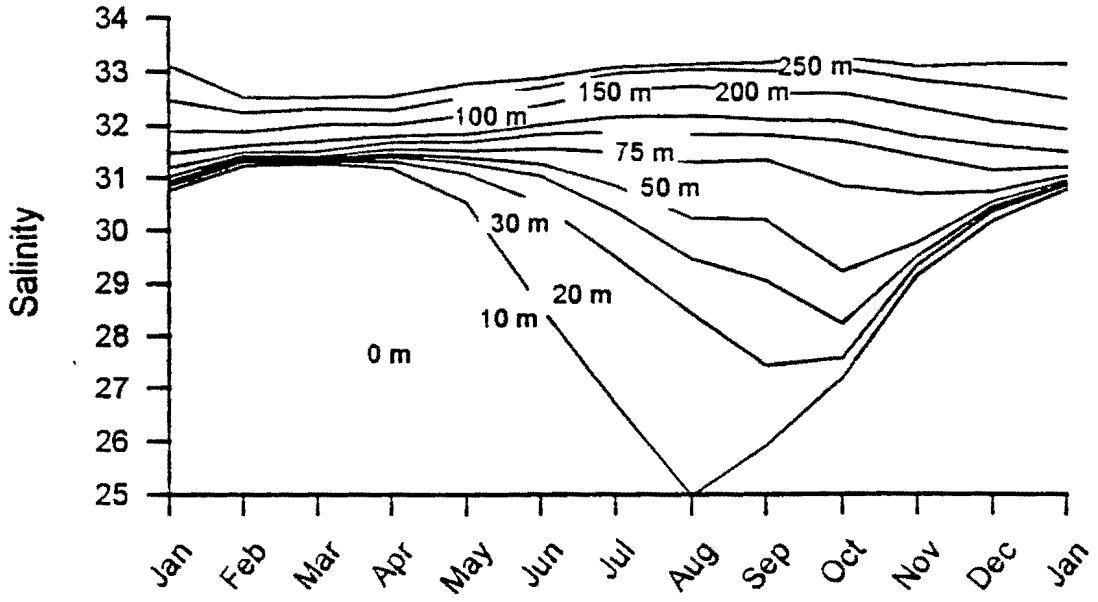


Figure 5. Mean monthly salinity at GAK1 as a function of depth. The means are computed from data collected between 1970 and 1996.

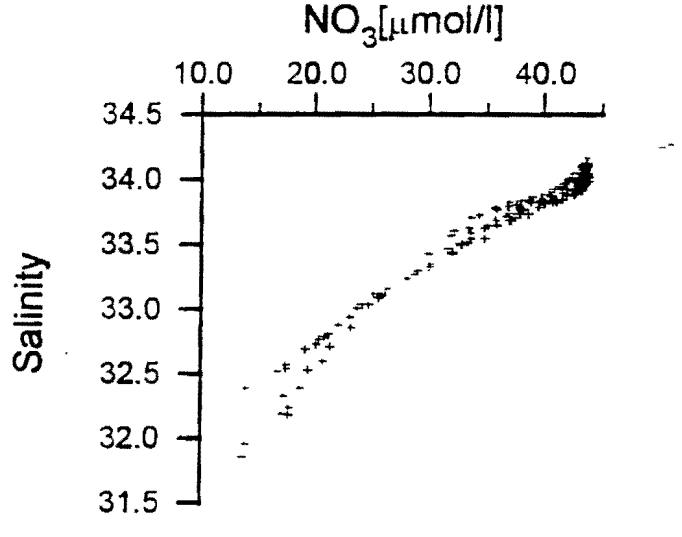


Figure 6. $NO_3$–salinity scatter plot from the shelf and slope of the northwest Gulf of Alaska in May–June 1993.

## PRINCIPAL INVESTIGATOR

**Thomas J. Weingartner**

### EDUCATION

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

### MEMBERSHIPS

American Geophysical Union; American Meteorological Society

### PUBLIC SERVICE

Member, Science Steering Committee, NSF - Arctic System Science-Ocean Atmosphere Ice Interaction (OAII) component
Member, Science Steering Committee, NSF - ARCSS-OAII Shelf-Basin Initiative
Member, Science Steering Committee, NSF - ARCSS-Human Dimensions of the Arctic component
Member, UNOLS - Fleet Improvement Committee

### 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

Weingartner, T. J., S. Danielson, Y. Sasaki, V. Pavlov, and M. Kulakov. The Siberian Coastal Current: a wind and buoyancy-forced arctic coastal current. *J. Geophys. Res.*, submitetd.

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Niebauer, H. J., Royer, T. C., and T. J. Weingartner. 1994. Circulation of Prince William Sound, Alaska. *J. Geophys. Res..* 99:14113-14126

Coyle, K. O., G. L. Hunt, M. B. Decker, and T. Weingartner. 1992. The role of tidal currents in concentrating euphausiids taken by seabirds foraging over a shoal near St. George Island, Bering Sea. *Mar. Ecol. Progr. Ser.* 83:1-14.

Musgrave, D. L., T. J. Weingartner, and T. C. Royer. 1992. Circulation and hydrography in the northwest Gulf of Alaska. *Deep-Sea Res.* 39:1499-1519.

Weingartner, T. J. and R. H. Weisberg. 1991. A description of the annual cycle in sea surface temperature and upper ocean heat in the equatorial Atlantic. *J. Phys. Oceanogr.* 21:83-96.

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**Manuscripts in preparation:**

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

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

## 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. Mark Vallarino is the computer programmer who will assist in data processing, analysis, and establishing the web page. Both are employees of the Institute of Marine Science.

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Weingartner, T. Toward long-term Oceanographic Monitoring of the Gulf of Alaska Ecosystem, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 98340).

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**2000 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Personnel | | $0.0 | | | | | | |
| Travel | | $0.0 | | | | | | |
| Contractual | | $64.9 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | | | | | | |
| Subtotal | | $64.9 | | | Estimated FY 2001 | Estimated FY 2002 | | |
| General Administration | | $4.5 | | | | | | |
| Project Total | | $69.4 | | | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.5 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

**FY00**

Project Number: 00340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Prepared:

**2000 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $37.5 |
| Travel | | $2.1 |
| Contractual | | $10.2 |
| Commodities | | $2.1 |
| Equipment | | $0.0 |
| Subtotal | | $51.9 |
| Indirect | | $13.0 |
| Project Total | | $64.9 |
| Full-time Equivalents (FTE) - | | 0.5 |
| Other Resources | | |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | | Estimated FY 2001 | Estimated FY 2002 | | |
| | | $67.3 | | | |
| Dollar amounts are shown in thousands of dollars. | | | | | |
| | | | | | |

Comments:

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

**FY00**

Prepared:

Project Number: 00340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: Thomas J. Weingartner

FORM 4A
Non-Trustee
SUMMARY

**2000 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 2000 |
| Weingartner, T. | Principal Investigator/Assistant Prof. | | 2.0 | 6.4 | | 12.8 |
| Vallarino, M. | Computer programmer | | 2.0 | 5.3 | | 10.6 |
| Leech, D. | Mooring and marine technician | | 2.5 | 5.2 | 1.1 | 14.1 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 6.5 | 16.9 | 1.1 | |
| | | | | | **Personnel Total** | $37.5 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| Description | | Price | Trips | Days | Per Diem | FY 2000 |
| R/T Fairbanks to Anchorage | | 300.0 | 1 | 3 | 120.0 | 0.7 |
| Fairbanks to San Antonio, TX | | 750.0 | 1 | 5 | 125.0 | 1.4 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $2.1 |

**FY00**

Prepared:

Project Number: 00340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: Thomas J. Weingartner

FORM 4B
Personnel
& Travel
DETAIL

**2000 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Little Dipper (6 days @ $500/day) | 3.0 |
| CTD calibration (SBE-25) | 0.6 |
| Microcat calibration (6 @ $600 ea.) | 3.6 |
| Acoustic release alighnment | 1.0 |
| Shipping (R/T Seward to Seattle, CTD and MicroCats) | 1.0 |
| Shipping (R/T Seward to Boston, acoustic release) | 1.0 |
| **Contractual Total** | $10.2 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Batteries, O-rings, tools | 1.0 |
| Shackles, sling links, thimbles | 0.5 |
| Standard seawater (6 @ $30/vial) | 0.2 |
| Mooring anchor and lashing chain | 0.4 |
| **Commodities Total** | $2.1 |

**FY00**

Prepared:

Project Number: 00340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: Thomas J. Weingartner

FORM 4B
Contractual & Commodities DETAIL

**2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **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 |
| 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 |
|---|---|
| | |

**FY00**

Project Number: 00340
Project Title: Toward Long-Term Oceanographic Monitoring of the Gulf of Alaska Ecosystem
Name: Thomas J. Weingartner

FORM 4B Equipment DETAIL

Prepared:

# Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet

| | |
|---|---|
| Project Number: | 00341 |
| Restoration Category: | Research |
| Proposer: | University of Alaska Fairbanks |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | none |
| Alaska SeaLife Center: | yes |
| Duration: | 3rd year, 4-year project |
| Cost FY 00: | $123,638 |
| Cost FY 01: | $90,018 |
| Cost FY 02: | none |
| Geographic Area: | Kenai Peninsula, Seward |
| Injured Resource/Service: | Harbor seal |



## ABSTRACT

This program continues a long-term study currently underway at the Alaska SeaLife Center, quantifying the impact of feeding specific diets on the health and body condition of harbor seals. Even though health status biomarkers for marine mammals in Prince William Sound were established during EVOS supported field trials, the critical test of how markers vary in an individual as a result of eating specific prey has not been conducted. We will also establish whether specific diets are nutritionally adequate to maintain seal health by monitoring health parameters and measuring assimilation efficiency during feeding trials. While this project focuses on harbor seal health, the approach is applicable to other injured top predators.

## INTRODUCTION

An underlying component of the ecosystem-based research approach supported by the Trustee Council has been the hypothesis that food limitation could be inhibiting the recovery of injured species in Prince William Sound (PWS). Inherent in this concept is the assumption that food stressed animals can be distinguished by population-wide surveys of critical health parameters. Following this approach, an extensive sampling effort by multiple projects established a series of biomarkers used to profile the health and body condition of wild populations of marine mammals inside PWS. Population health status and body condition indices were, and continue to be, developed and tested for a range of birds, river and sea otters and seals. On the basis of this wide-ranging effort, reference range values for these health parameters have been established and are being used to compare whole groups of animals across time and space (1–8). This approach is critical to understanding how these markers work on a population health level.

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

The Trustee Council has supported the population-monitoring component of health biomarkers for marine mammals in Prince William Sound. At the Alaska SeaLife Center (ASLC) in Seward, we are testing those biomarkers under controlled conditions, in the same animals over time (particularly seasonally) and under changing experimental conditions. Of particular interest is the effect of specific diets on harbor seal physiology. This will address the question of food limitation more completely, including the suggestion that certain prey may not be nutritionally adequate. Work on birds using the basic elements of this concept has already been initiated (6).

The Alaska SeaLife Center took possession of eight harbor seals in April 1998 and the acclimation phase of the study was completed in fall, 1998. The health and condition of the animals was closely monitored (weight, morphometrics and biweekly blood samples). These baseline data are being compiled into a database for use in interpreting data collected during controlled diet experiments. The database currently includes values for standard veterinary chemical and hematological values, standard morphological measurements including mass, length and girths, and ultrasound measurements to assess blubber depth. In addition, samples have been collected to determine levels of various biomarkers being used in field studies,

including haptoglobin, erythrocyte sedimentation rated (ESR), nitric oxide, metallothionien and associated levels of copper and zinc (EPA G71A0086). The SeaLife Center also successfully rehabilitated three harbor seal pups during the summer of 1998 (2 injured/unhealthy and 1 possibly abandoned). Each of the pups was monitored carefully, including weekly morphometric measurements and blood samples. Blood and morphometric measurements were consistent with recovery, although all three seals exhibited decreasing hematocrit and triglyceride levels.

Feeding protocols have been established in conjunction with the ASLC veterinarian and pinniped husbandry staff. After acclimation, six seals were placed on experimental diets of specific prey items (herring or pollock). These diets will be switched every four months for two years. The four month periods correspond to three seasons – winter/molt, spring and summer. At the end of two years, each seal will have been on each diet during each season. Two seals have been placed on a mixed diet for the duration of the study. The first feeding trial began in September 1998. Monitoring of health and condition has continued, including biweekly measurement of weight, morphometrics and blood sampling. Assimilation efficiency experiments were conducted for each animal in December 1998 and the first feeding trial concluded in January 1999. While data are being compiled from this first feeding trial, they are still too preliminary to report. The seals are currently in the middle of their second feeding trial.

The animals being used in this study are also involved in two other EVOS funded Restoration Projects. Using the same feeding protocols, Project 99371 is conducting experiments on stable isotope analysis as diet changes and Project 99441-BAA is conducting experiments on fat metabolism.

Fish being used as prey in this study are analyzed for % water, % lipid, % nitrogen and energy density. These analyses will be conducted regularly throughout the study to monitor different fish batches and any nutritional changes that may occur during food storage. Mean lipid content ($\pm$ S.D; wet mass basis) for herring used in the first feeding trial was $16.0 \pm 1.5$ % ($n = 5$), compared to pollock which was $5.0 \pm 0.9$% ($n = 5$). Mean energy density ($\pm$ S.D.; wet mass basis) for herring was $9.2 \pm 0.8$ kJ/g ($n= 10$) compared to $5.2 \pm 0.4$ kJ/g ($n = 5$) for pollock. There has been no loss of lipid or energy density over 2 – 3 months in frozen storage, so herring and pollock being used for the second feeding trial have similar compositions to those used in the first trial.

Steve Trumble (Ph.D. student associated with this project) has been working with Dr. P. Barboza at UAF to determine assimilation efficiency and metabolizable energy of specific prey items using inert marker techniques. In addition, he has participated in three field expeditions (supported by ADF&G) in which he was responsible for measuring health biomarkers in harbor seal pups. Tami Mau (Ph.D. student associated with this project) has been analyzing the blood lipid profiles in the seals on differing diets.

## NEED FOR THE PROJECT

### A. Statement of Problem

The Restoration Program has established a strong field component that has tested a series of

health and body condition biomarkers for many of the top-level predators in the Sound (2, 3, 5–7), including harbor seals (1, 4, 8). Many of these indices are related to metabolic alterations that might occur in animals that are food limited, or stressed. These include markers for fat, protein and carbohydrate metabolism (fatty acid patterns, blood urea nitrogen, ketone bodies, glucose), water balance (plasma and whole blood water), blubber quality in harbor seals (energetic density, lipid distribution, histology) and total body fat. Other markers have addressed more health or contaminant related issues such as indicators of oil contamination (P450, PAH), whole body inflammatory response (haptoglobin, interleukin), organic residue contamination (PCB) and clinical indicators of disease state (clinical chemistry panels, blood hemograms).

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

Recent results from a number of EVOS Restoration Projects (presented at Legacy of an Oil Spill: 10 Years After the *Exxon Valdez* Oil Spill; APEX and NVP) have demonstrated the critical nature of food composition to the growth, and potentially success, of several injured species. The physiological response of seals to diets markedly different in lipid and energy content (assimilation efficiency, metabolizable energy, passage rate) are being assessed in captive seals fed the same controlled diets being used for monitoring of health parameters.

**B. Rationale/Link to Restoration**

If we theorize that various health and body condition markers react in the field to ecosystem-wide changes in food availability or animal health, then we should be able to quantify those mechanisms in the laboratory under controlled conditions. The SeaLife Center has research animals that are healthy and have been put onto differing diets of specific prey. In addition, it has sick animals that are brought in for rehabilitation. Both groups allow us to examine how these health markers respond to food and health status. Experiments following the same conceptual protocol have been carried out in Europe on harbor seals fed diets of fish that differed in contaminant loads (9). In those studies, it was found that seals fed contaminated fish showed measurable decreases in immune function. In this program, we are not feeding contaminated fish, but rather fish of differing energy densities (pollock and herring) and monitoring sick animals that are at the Center for rehabilitation. These "rehab" animals represent seals whose ability to survive in the wild has been compromised, and they present a unique view into the biology of sick animals that are under-represented in our field studies in the Sound (8).

An additional rationale for this project concerns the "junk food" hypothesis. One of the most popular hypotheses concerning the cause for the decline of marine mammals and birds in Alaskan waters was first voiced at a Sea Grant sponsored workshop in 1991 on whether or not food limitation could account for the observed population patterns (10). At that workshop, the "junk food" hypothesis was proposed. This thesis stated that Alaskan waters had a sufficient

biomass of pollock to support the harbor seal and Steller sea lion populations, ***but*** pollock was nutritionally poor compared to other less common species, such as herring and capelin. Because the marine ecosystem of Alaska experienced a regime shift in the late 1970s that moved the system from a groundfish/herring-based food web to a pollock-dominated food web, the high-energy food that pinnipeds used to eat simply disappeared. Thus, the hypothesis proposes that seals and sea lions may be starving in a sea full of pollock. The presence of The Alaska SeaLife Center allows us to critically test this hypothesis.

### C. Location

The experiments for this work are being conducted at the Alaska SeaLife Center in Seward. Similar experiments were conducted on pigeon guillemots at ASLC during 1998 (Restoration Project /327). Additional studies on harbor seals (Restoration Project 99371 and 99441-BAA) have begun and use the same feeding framework for their experiments. Thus, there is considerable collaboration among the projects and significant sharing of resources and personnel. Similar experiments are underway with Steller sea lions through funding provided by the National Fish and Wildlife Foundation.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The field work on harbor seals has involved integral collaboration with Native communities throughout the Gulf region in conjunction with the BIOSAMPLING program (Project /244) and we anticipate Native collaboration to continue. Given that the Alaska SeaLife Center, the EVOS Trustee Council, the Alaska Native Science Commission and the Alaska Native Harbor Seal Commission are all currently working on joint scientific collaboration, we expect this project to include involvement with Native communities. Harbor seals are important food items for these communities, and results of these and previously funded studies will continue to be shared with the Native Communities at the Alaska Native Harbor Seal Commission meetings.

An important mission of the Alaska SeaLife Center is to educate the public about unique Alaskan habitats and the importance of stewardship. The Center spotlights the role that research plays in understanding and contributing to the stewardship of that environment. Research done at the SeaLife Center is highly visible both to local communities as well as several hundred thousand visitors each year. Researchers involved in this study volunteer time at the SeaLife Center to present information directly to the public, including school groups, and to provide updated information about the project to the Education Department.

## PROJECT DESIGN

### A. Objectives

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

1. Feed controlled diets of pollock and herring to harbor seals.

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

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

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

**B. Methods**

Feeding schedules and timing patterns of controlled diets have been developed in conjunction with the ASLC veterinarian and pinniped staff. There are other EVOS-funded research personnel that are taking advantage of the controlled-diet protocols and the design allows for the accommodation of these needs. In particular, EVOS Restoration Projects /441-BAA and /371 utilize the same feeding schedules to conduct their work on lipid metabolism and stable isotope biochemistry.

Eight harbor seals are currently in residence at the ASLC and are involved in this project. Each animal is examined every two weeks for all measurements and all are trained to submit voluntarily to morphometric measurements and to voluntarily move onto scales to obtain mass values at least once a week. Three seals have been successfully trained to allow voluntary blood sampling from the extradural vein and desensitization is continuing with the others. Groups of seals began exposure to experimental diets in September, 1998. The eight animals are evenly split male/female, while four are mature animals and four are young.

***Food maintenance trials***

A detailed matrix of the feeding schedule is shown below. The procedure utilizes a cross-over repeated measures approach that allows statistical comparisons within any one group of seals between diet and season. Statistical software (SYSTAT) is being used to analyze the cross-over method.

***CROSS-OVER REPEATED MEASURES ANOVA***
***FEEDING TRIALS FOR HARBOR SEALS***

| PERIOD | HERRING | POLLOCK | CONDITION |
|---|---|---|---|
| Sept–Dec 1998 | Seals A,B,C | Seals D,E,F | Molting |
| Jan–Apr 1999 | D,E,F | A,B,C | Spring |
| May–Aug 1999 | A,B,C | D,E,F | Breeding |
| Sept–Dec 1999 | D,E,F | A,B,C | Molting |
| Jan–Apr 2000 | A,B,C | D,E,F | Spring |
| May–Aug 2000 | D,E,F | A,B,C | Breeding |

Two seals (G, H) are in a separate feeding group. They are being fed a mixed diet of herring and pollock throughout the study. These animals undergo the same procedures as the animals on single prey diets.

This feeding matrix allows each group of seals to experience a different diet at similar physiologically relevant times of the year. Group A,B,C for example, was fed a herring diet during molting season in year one and will be fed a pollock diet in year two. While all the harbor seals in this study were maintained previously on diets high in herring, they have all easily switched to experimental diets.

A problem with cross-over ANOVA designs is that residual or carry-over effects from previous treatments can complicate the analyses. We correct for this with extremely long test periods and phased cross-overs. That is, since each feeding trial will last for four months, several weeks of diet switching will be allowed. This provides the additional advantage of allowing us to study the biochemical impact of the phased switch.

In any captive situation, the behavior of the pinniped may influence feeding patterns, especially if the diet changes in palatability (11, 12). Fortunately for this study, both fish species are part of the natural diet of harbor seals. In addition, feeding trials extend for four months and trainers work with the animals continually on feeding behavior. Animals are switched gradually from one diet to another over several weeks as the percentage of herring or pollock is adjusted. At this point in the study (middle of second feeding trial), each animal has switched from herring to pollock with no resistance.

Under controlled feeding conditions, the feeding frequency during any given day impacts issues such as satiation, over-feeding, etc. The trainers and husbandry personnel maintain a regular and adequate food intake and make sure that the animals are fed at the same time each day (13).

An additional consideration is the number of animals per feeding trial. As shown above, we stagger animals through these long-term feeding schedules; however, three to six animals per trial are commonly used (13) and considered adequate for determinations of digestive efficiency.

Long-term alterations in the basic metabolic needs of the animals will occur as a result of annual cycles (e.g., molting). The metabolic demand of phocids varies throughout the year (14–15). We assume that the absolute number of maintenance calories per unit time will change seasonally. Therefore, we must be able to factor that change into any nutritional limitations of the food itself. We must measure these long-term changes to accurately interpret the biochemical profiles obtained from the field data. To offset these problems we have implemented the staggered feeding regime shown above. We have separated the seals into two groups of three, one feeding on a different food item than the other. Each group is fed on a given food item for at least four months, then alternates with another group at the end of each four-month trial. These feeding trials will continue for two years, exposing each animal to various seasonal or yearly cycles with each prey species. This will provide standard deviations in assimilation efficiency, digestive efficiency and metabolizable energy while minimizing potential errors associated with temporal fluctuations (season or year) or metabolism (e.g., molting) and confounding errors associated with each prey item during a particular feeding trial. Although staggered feeding methods have

been utilized in captive bird studies (16) few data exist on long-term assimilation studies for captive marine mammals.

The final issue is the application of laboratory data to the field environment. *We are not proposing to model the metabolic demands of harbor seals in the wild.* The stresses and food requirements of wild populations are very different from captive animals. Instead, we are investigating the metabolic response to differing diets and the effect of these diets on blood chemistry, blubber physiology and body condition of these animals. That is, we do not seek to model how may calories an animal may consume per month and apply that to field estimates of mass of fish consumed at sea. *We will quantify how blood chemistry biomarkers change when an animal is fed several different kinds of fish and compare those chemical changes to observed patterns already collected from wild populations.* This study is designed to investigate whether fish diets and seasonal alterations in food demand impact these chemical levels.

The food provided to the seals comes from frozen stocks of Alaska herring and pollock held by the ASLC husbandry collection. The fish are analyzed for body composition and inventoried by batch number so that any variation in food composition can be monitored. Analyses include %water (freeze drying), %lipid (Soxhlet extraction), %nitrogen (Kjeldahl extraction) and energy density (bomb calorimetry). Fish that are stored long-term are re-analyzed every one to three months, depending on degree of compositional change observed.

***Body condition, health and blood chemistry alterations***

BODY CONDITION

Seals are weighed at least at every biweekly handling. The trainers continue to work to establish voluntary behaviors, and the seals are often weighed several times a week. At biweekly handling times, measurements of length, girth and blubber depth (using portable ultrasound) are collected. Every 4 months, whole body bio-impedance (BIA) is measured as a proxy for water content and calibrated with labeled water. In this technique, deuterated water ($D_2O$) is injected into the seal, allowed to equilibrate with the total body water and then blood samples are drawn to measure $D_2O$ dilution. This is a routine procedure for body water determination and we have used it on both Steller sea lions and harbor seals. In order to facilitate the field/laboratory comparisons, these morphological indices are the same as those we developed for use on wild populations of pinnipeds. Models of the most sensitive indicators for the field animals exist for harbor seals (1, 8).

BLOOD CHEMISTRY

To date, we have a database of blood indices from over 450 adult harbor seals and 100 harbor seal pups as well as 300 Weddell seals, 400 Steller sea lion pups, 40 Steller sea lion juveniles and over 80 Steller sea lion adults collected under field conditions. These indices include not only clinical veterinary panels of blood chemistry and hematology, but also additional indicators we have developed for specialized use on pinnipeds.

Blood samples are collected every two weeks from each animal throughout the duration of the study. The blood sample is taken from the extradural sinus directly into the appropriate vacuum collection tube. We routinely take blood into both EDTA (for hematology) and heparin tubes (for chemistry). The blood is analyzed on site for most of the metabolites and hematological parameters of interest. Because these animals are highly trained for research protocols, this

frequency of handling has not induced any negative behaviors that could compromise the project. All eight seals have been handled by research teams for many years and have easily adapted to their new protocols.

One of the implications of the junk food hypothesis is that the impacted animals are nutritionally stressed. Therefore, we have developed a series of blood indicators for fieldwork that provides a profile of the fasting and starvation status of pinnipeds. These markers include *ketone bodies* (metabolites produced to support neural function in the face of decreasing food intake), *blood urea nitrogen* (marker for increased muscle tissue degradation during starvation), *differential fatty acid utilization* (selective utilization of fat from lipid stores in the blubber during fasting), *water balance* in the plasma (particularly sensitive as pups gain nutritional independence) and red cell characteristics including *hemoglobin content/cell* and *mean cell volume*. We have found these markers to be useful in determining whether or not pinnipeds are feeding, fasting, or entering starvation in the wild (17, 18, 19, 20).

***Nutritional assimilation***

Estimating prey or nutritional requirements of a predator using an energy model necessitates that assimilation efficiency be quantified (21). Assimilation efficiency (AE), which is defined as the proportion of dry matter assimilated from a prey source, is influenced by food quality, meal size, feeding frequency and digestive passage rate (22, 23, 24,). Recent studies have suggested that assimilation efficiency is low when food quality is low (16, 25). For example, harp seals (*Phoca groenlandica*) fed Atlantic herring or capelin had a higher AE and consumed less food than those fed invertebrates of lower energy density (25). However, conflicting results have been reported for harbor seals (14) and northern fur seals (11), while studies of California sea lions fed pollock did not show a significant decrease in AE with lower energy density food, such as pollock (26).

Once the seals have been established on a specific diet during each feeding trial, they will participate in two feeding experiments to quantify assimilation efficiency and metabolizable energy (ME). Each seal is fed a diet of the specific prey item(s), keeping other variables such as feeding frequency constant. In the first experimental regime, feeding frequency is four times a day, while in the second regime feeding frequency is once per day. The design and interpretation of feeding experiments takes into account the potential effects of seasonal variation in AE and ME and this is discussed above in the feeding trial design using staggered schedules. Each group of animals is moved from wet to dry holding areas at the ASLC so that fecal and urine samples can be collected as necessary.

For all animals, dietary prey and fecal samples are freeze-dried and analyzed for energy (kJ/g), nitrogen, total lipid, and ash. Bomb calorimetry will be used to determine energy density, nitrogen (protein) concentration will be determined using a carbon–nitrogen auto-analyzer, total lipid by Soxhlet extraction and ash by muffle furnace combustion. All these methods are routinely used at the UAF facilities and will be available at the SeaLife Center.

To determine digestibility of food absorbed in the digestive tract of seals, inert markers such as chromic oxide (solid phase) and cobalt-EDTA (liquid phase) will be added to the diets and subsequently assayed in fecal samples. These inert markers, along with naturally occurring manganese ($Mn^{2+}$) levels will be used to determine assimilation efficiency and compared with the digestibility results of a total balance trial. These markers have been used in pinniped AE

studies (26, 27) where dry matter digestibility has been calculated. Chromium, cobalt and $Mn^{2+}$ concentrations will be assessed using atomic absorption spectrophotometry (27). The tissue samples are extracted in Seward and analyzed by our own laboratory staff in Fairbanks.

In order to determine the passage of digesta (mean retention time), feces are collected during the feeding experiments. Rate of passage of digesta is one of the important factors that determine the efficiency of utilization of food (28). It has been documented in birds that the retention time of food in the gut is a function of food quality (29). In pinnipeds, such as the harbor seal, data indicate both high caloric prey items with soft parts and low caloric prey species have the fastest transit times through the digestive tract (30). However, the assimilation efficiency of the prey items fed to these seals was not known. Miller (11) reported that the passage rate of digesta in sub-adult female northern fur seals was rapid, although the AE appeared to be consistently high for the different prey items. Mean retention time will be calculated in order to examine its relationship with AE. If prey size and feeding frequency are equal in all trials, prey items with higher energy value should have shorter retention times and pass through the digestive tract more quickly. Methods used include the inert prey/feces markers chromic oxide and cobalt-EDTA.

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

The Marine Mammal Protection Act permit and internal UAF and ASLC Institutional Animal Care and Use Committee permits required for this project have been approved.

## SCHEDULE

### A. Measurable Project Tasks for FY 00 (October 1, 1999 – September 30, 2000)

Each feeding trial takes four months and work with sick animals may occur at any time of the year. Feeding trials began in September, 1998.

| | |
|---|---|
| September–December: | Trial 4 of staggered feeding protocol, monitoring condition and health of seals during period of molting. |
| December: | Assimilation efficiency experiments. |
| January–April: | Trial 5 of staggered feeding protocol, monitoring condition and health of seals during spring. |
| April: | Assimilation efficiency experiments. |
| May–August: | Trial 6 of staggered feeding protocol, monitoring condition and health of seals during breeding season. |
| August: | Assimilation efficiency experiments. |

### B. Project Milestones and Endpoints

Major milestones will continue as in the current year of this project. The three objectives listed above will be carried through the life of the project.

FY 00: Second full year of feeding trials; third year of stranded pups and/or rehabilitation animals.

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

### C. Completion Date

This project will finish on September 30, 2001.

## PUBLICATIONS AND REPORTS

During FY 00 we anticipate publishing short papers on how several of the health biomarkers change through seasons, in healthy vs sick animals, etc., with more comprehensive articles appearing in later years, once feeding trials have been completed.

The first annual report for this project, entitled Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet, has been submitted to the Trustee Council. This report presents baseline information about the seals before feeding trials were begun, as well as preliminary data on rehabilitated harbor seals. The second annual report will be submitted in FY00 and should contain results from the first series of feeding trials and more extensive analysis of data obtained from rehabilitated seals.

## PROFESSIONAL CONFERENCES

The PI requests funds to attend a major conference to work with colleagues who address issues of marine mammal physiology, ecology and conservation. Dr. Castellini has a long history of participating in these meeting (biennial Marine Mammal Conference) and it will occur in Hawaii in November. Work on this project will be presented at these meetings as well as at the EVOS annual meeting in January 2000 and the Alaska Native Harbor Seal Commission meeting in March 2000.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

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

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

This proposal is a continuation of Project 99341 with minor changes proposed from the original plan. The FY 99 DPD focussed on initiation of feeding trials with these animals. These trials depended on working out handling protocols and co-ordination with other projects. This process has resulted in small changes to the proposed plan, although the basic protocol remains unchanged. Rather than varying feeding frequency and meal size with just two seals fed a mixed

diet, feeding frequency variation has been incorporated into assimilation experiments for all seals. Two seals will still be fed an unchanging mixed diet throughout the study to serve as a control. The use of the dietary markers chromic oxide and cobalt-EDTA have been added to the assimilation experiments for several reasons. They will serve to further validate the use of $Mn^{2+}$ as a natural dietary marker and will also allow measurement of passage rate. Cobalt-EDTA is a soluble marker intended to measure the liquid component of the diet. Experiments have followed, and will continue to follow, the initially proposed timeline.

**PROPOSED PRINCIPAL INVESTIGATOR**

Michael A. Castellini
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**PRINCIPAL INVESTIGATOR**

Michael A. Castellini, Ph.D., specializes in metabolic chemistry problems associated with marine mammals. He is a tenured Professor of Marine Science at UAF and has worked in this field for over 25 years.

Publications by Dr. Castellini since 1990 relevant to the proposal include:

Castellini, M.A. and G.L. Kooyman. Length, girth, and mass relationships in Weddell seals (*Leptonychotes weddellii*). Marine Mammal Science. 6(1): 75–77. 1990.

Castellini, J.M., M.A. Castellini and M.B. Kretzmann. Circulatory water balance in suckling and fasting northern elephant seal pups. Journal of Comparative Physiology B. 160(5): 537–542. 1990.

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Castellini, M.A., R.W. Davis, T.R. Loughlin and T.M. Williams. Blood chemistries and body condition of Steller sea lion pups at Marmot Island, Alaska. Marine Mammal Science. 2: 202–208. 1993.

Castellini, J.M., H.J. Meiselman and M.A. Castellini. Understanding and interpreting hematocrit measurements in pinnipeds. Marine Mammal Science. 12: 251–264. 1996.

Zenteno-Savin, T., M.A. Castellini, L.D. Rea and B.S. Fadely. Plasma haptoglobin levels in threatened Alaskan pinniped populations. Journal Wildlife Diseases. 33(1): 64–71. 1997.

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Zenteno-Savin, T., M.A. Castellini. Plasma angiotensin II, arginine vasopressin and atrial natriuretic peptide in free ranging and captive seals and sea lions. Comparative Biochemistry and Physiology. 119C:1-6. 1998.

## OTHER KEY PERSONNEL

J. M. Castellini, M.Sc., is a UAF Research Associate and has worked on marine mammal biochemistry/physiology projects since 1986. She is currently the laboratory director and provides daily project monitoring. Her role includes blood chemistry analysis, proximate analysis of prey, quality control, computer analysis and publication preparation.

Steve Trumble received his M.S. degree in 1995 from California State University Fresno (Moss Landing Marine Laboratory) where he worked on the feeding pattern and lactation habits of harbor seals. He has completed work on the second year of a UAF Rasmuson Fisheries Research Fellowship for his proposed Ph.D. thesis on feeding patterns and health issues for harbor seals in Alaska. This proposal deals with the laboratory component of his thesis and support from ADF&G covers the field component. He has completed two field seasons investigating health and development of harbor seal pups at Tugidak Island, Alaska. No salary is requested as it is covered by the Rasmuson Fellowship.

Tami Mau is a Ph.D. student working on lipid chemistry patterns in marine mammals. Her component of this project involves analysis of blood lipid profiles. She is also responsible for collection and processing of samples and data analysis.

## LITERATURE CITED

1. EVOS Project 96001. Recovery of harbor seals from EVOS: Condition and health status.

2. EVOS Project 96102. Comprehensive killer whale investigations in Prince William Sound.

3. EVOS Project 96025. Mechanisms of impact and potential recovery of nearshore vertebrate predators.

4. EVOS Project 96064. Monitoring, habitat use and trophic interactions of harbor seals in Prince William Sound.

5. EVOS Project 96163G. Diet composition, reproductive energetics and productivity of seabirds damaged by the *Exxon Valdez* Oil Spill.

6. EVOS Project 96163N. Effects of diet quality on post-natal growth of seabirds: Captive feeding trials.

7. EVOS Project 96170. Isotope ratio studies of marine mammals in Prince William Sound.

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9. Ross, P.S., R.L. de Swart, H.H. Timmerman, P.J.H. Reijnders, J.G. Vos, H. Van Loveren and A.D.M.E. Osterhaus. 1996. Suppression of natural killer cell activity in harbour seals fed Baltic Sea herring. Aqua. Tox. 34:71–84.

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19. Rea, L.D., M.A. Castellini, B.S. Fadely, T.R. Loughlin. 1999. Health status of young Alaska Steller sea lion pups as indicated by blood chemistry and hematology. Comp. Biochem. Physiol. In Press.

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**2000 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Personnel | | $0.0 | | | | | | |
| Travel | | $0.0 | | | | | | |
| Contractual | | $115.6 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | | | | | | |
| Subtotal | $0.0 | $115.6 | | | Estimated FY 2001 | Estimated FY 2002 | | |
| General Administration | | $8.1 | | | | | | |
| Project Total | $0.0 | $123.7 | | | $90.0 | $0.0 | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 1.5 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

**FY00**

Prepared:

Project Number: 00341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Studies
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

## 2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $52.3 |
| Travel | | $9.2 |
| Contractual | | $23.6 |
| Commodities | | $7.4 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $92.5 |
| Indirect | | $23.1 |
| Project Total | $0.0 | $115.6 |
| Full-time Equivalents (FTE) | | 1.5 |
| Other Resources | | |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | | Estimated FY 2001 | Estimated FY 2002 | | |
| | | $90.0 | $0.0 | | |

Dollar amounts are shown in thousands of dollars.

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 resident tuition of $3,006 per year.

**FY00**

Prepared:

Project Number: 00341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Name: Michael A. Castellini, University of Alaska Fairbanks

FORM 4A
Non-Trustee
SUMMARY

**2000 EXXON VALDEZ TRU COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Personnel Costs: Name | Position Description | | Months Budgeted | Monthly Costs | Overtime | Proposed FY 2000 |
|---|---|---|---|---|---|---|
| | | | | | | 0.0 |
| Castellini, M | Principal Investigator/Professor | | 2.5 | 7.7 | | 19.3 |
| Castellini, J. M. | Research Associate | | 3.0 | 4.6 | | 13.8 |
| | Ph.D. Student | | 12.0 | 1.6 | | 19.2 |
| | | | | | | 0.0 |
| | Adjustment to recognize rounding | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 17.5 | 13.9 | 0.0 | |
| | | | | | **Personnel Total** | $52.3 |

| Travel Costs: Description | Ticket Price | Round Trips | Total Days | Daily Per Diem | Proposed FY 2000 |
|---|---|---|---|---|---|
| | | | | | 0.0 |
| Fairbanks to Anchorage for annual EVOS meeting (2 people) | 0.3 | 1 | 10 | 0.1 | 1.3 |
| Fairbanks to Anchorage for EVOS workshop | 0.3 | 1 | 5 | 0.1 | 0.8 |
| Fairbanks to Codova for annual meeting of Alaska Native Harbor Seal Commission | 0.3 | 1 | 3 | 0.1 | 0.6 |
| | | | | | 0.0 |
| Fairbanks to Seward to oversee research at the ASLC | 0.3 | 8 | 16 | 0.1 | 4.0 |
| Fairbanks to Maui for Marine Mammal Conference (2 people) | 0.6 | 2 | 10 | 0.1 | 2.2 |
| | | | | | 0.0 |
| Adjustment to recognize rounding | | | | | 0.3 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $9.2 |

**FY00**

Prepared:

Project Number: 00341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Name: Michael A. Castellini, University of Alaska Fairbanks

FORM 4B
Personnel
& Travel
DETAIL

**2000 EXXON VALDEZ TRU: COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Contractual services (blood - veterinary analysis) | 15.0 |
| Contractual services (prey analysis) | 2.9 |
| Contractual services (additional animal services) | 3.2 |
| Communications | 1.0 |
| Publication/disseminations | 1.5 |
| **Contractual Total** | $23.6 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Laboratory expendables for collection of blood samples | 3.0 |
| Laboratory expendables for collection and storage of other samples (fece, urine, prey) | 1.6 |
| Laboratory expendables for analysis of samples | 2.8 |
| **Commodities Total** | $7.4 |

**FY00**

Prepared:

Project Number: 00341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Name: Michael A. Castellini, University of Alaska Fairbanks

FORM 4B
Contractual & Commodities
DETAIL

**2000 EXXON VALDEZ TRU[illegible] COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | 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 |
| 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 | |
| | | |

**FY00**

Project Number: 00341
Project Title: Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet
Name: Michael A. Castellini, University of Alaska Fairbanks

FORM 4B
Equipment
DETAIL

Prepared:

# FATTY ACID PROFILE AND LIPID CLASS ANALYSIS FOR ESTIMATING DIET COMPOSITION AND QUALITY AT DIFFERENT TROPHIC LEVELS

| | |
|---|---|
| Project Number: | 00347 |
| Restoration Category: | Research Monitoring |
| Proposer: | Ron A. Heintz, M. Larsen<br>NMFS, Auke Bay Laboratory<br>ABL Project Manager: Dr. Stan Rice<br>NOAA Program Manager: Bruce Wright |
| Lead Trustee Agency: | NOAA |
| Alaska Sea Life Center: | No |
| Duration: | 3rd year, of 3-year project |
| Cost FY 00: | $44.7 |
| Geographic Area: | Prince William Sound, Lower Cook Inlet |
| Injured Resource/Service: | Various |



## ABSTRACT

This is the close-out for the project which began the systematic development of fatty acid profiles and lipid class analysis to identify diet differences and quality in forage fish and their prey. Specifically, we have examined the spatial and temporal variability of fatty acid profiles in herring, sandlance, and zooplankton, and related this to the nutritional condition of these important forage fish. In FY98 we began the spatial comparisons which provided insight into the energetic differences in forage fish in disparate parts of PWS. In FY99 we made temporal comparisons which will provide information on the energetic changes that inevitably occur with seasonal, ontogenetic, and reproductive changes. All these comparisons are based on samples collected by APEX investigators. In FY2000 we propose the closeout of this project entailing a statistical analysis and report on the spatial, temporal, and ontogenetic variation of data. Results of these studies will benefit APEX investigators by demonstrating the utility of fatty acid analysis for establishing dietary and energetic differences between aggregates of forage fish.

## INTRODUCTION

This project seeks to extend the utility of fatty acid (FA) analysis for estimating diet composition, by relating FA compositions in forage fish to their prey and examining the nutritional condition of these animals through lipid class analysis. Iverson et al (in press) have indicated that FA profiles in seals in Prince William Sound (PWS) reflect the profiles found in their prey. In view of its promise, the utility of FA analysis for estimating diet composition warrants investigation in other predators.

FA can be viewed as the energetic currency that is exchanged when predators consume prey. After consumption, some fraction of the consumed FA are used to provide energy for the Krebs cycle, and surplus FA are distributed via the blood stream to fat depots located throughout the organism. Examination of the FA composition of the surplus FA affords an integrated view of the FA derived from a predator's prey. Iverson (in press) has concluded that changes in a predator's FA composition occur within a short time. Thus, while examination of the FA composition may provide insight into diet composition, it is important to know how sensitive this tool is to the variations in diet.

Before FA analysis for estimating diet composition can be extended, the basic assumption that a predator's FA composition resembles its prey requires demonstration and the sources of variation underlying the FA composition need to be described. The basic assumption has been investigated under laboratory conditions, but not tested in the field. This assumption indicates the sources of variation in the FA profiles of their prey must be quantified because a predator's FA profile will be influenced by the FA available in its foraging range. In fact, Iverson et al. (In press) reported spatial and ontogenetic variation in herring FA profiles, but the spatial and temporal scales of this variability have not been defined. In FY98 this project began analyzing the spatial scale of variation in herring and sandlance. In FY99 we are examining the temporal scale and life stage dependent variations in sandlance. We propose a closeout of this project in FY2000 including statistical analysis, interpretation, and summary of the data.

Initial observations of the spatial data (FY98 component) indicate that in sandlance and herring only a small number of FA can be used to discriminate spatial differences and that the discriminating FA are different for each species. Also, the FA profile of sandlance varies significantly with the size of fish within one age class indicating a strong sensitivity to developmental stage. Integrating spatial, species, size, and potentially temporal (FY99 component) dependent variations in the FA of forage fish makes data analysis very complicated. These variations in forage fish must be better understood and documented or the complexity of analysis will be inherently exaggerated in higher trophic levels.
Examination of the relative abundance of lipid classes in organisms provides a measure of their surplus energy, i.e., their nutritional condition. Lipids can be classified by their structure into several classes. Each class represents lipids used for either membranes, energy reserves, structural elements or hormones. Comparing the relative abundance of the energy reserve class, triacylglycerols (TAG) in fishes and wax esters in zooplankton, to the total amount of lipid

provides a measure of the relative amount of energy reserve. This measurement is a much more accurate indicator of nutritional condition than is the percent total lipid traditionally reported for specimens. Combining observations of dietary differences with evaluations of stored energy can lead to extremely powerful interpretations of efficiencies in predator prey relationships. This power is easily obtained since FA analysis for estimating diet composition is most sensitive when performed on the energy reserve portion of the total lipid of a predator. Thus, lipid class analysis is the first step to analyzing FA composition. Initial observations indicate that energy reserves (TAG content) in sandlance and herring vary significantly over relatively small spatial scales suggesting the potential of this analysis for identifying trends in productivity. No trends in energy acquisition have been observed coincident with co-ocurring populations of sandlance and herring indicating that competition does not limit their ability to acquire energy.

We propose to complete the statistical analysis and reports for two field surveys that were designed to demonstrate 1) the spatial and temporal scales of variation in the FA profiles of important forage fish in PWS and lower Cook Inlet, and 2) the analysis of FA profiles and lipid class analysis for examining the nutritional consequences for predators consuming different diets. These surveys initiated the systematic development of these techniques for examining broad scale trophic relationships. Specifically, the studies provide detailed information on the spatial and temporal variability of FA profiles in sandlance and herring as well as measuring the consequences of dietary differences by evaluating the availability of surplus energy. An objective of the first year of this study, FY98, proposed to examine the spatial variability of FA profiles of herring, sandlance, and zooplankton collected at different sites in PWS by APEX 163A investigators. These samples have been processed and are currently being statistically analyzed. In FY99, the temporal variability of FA is being examined by processing sandlance samples collected every 2 weeks from May through August, 1998, by APEX 163M investigators in Lower Cook Inlet. The investigation into the temporal and spatial variation will be supplemented with samples collected opportunistically from June through August by APEX 163E investigators working near Point Eleanor in Prince William Sound. These samples have been processed in the laboratory, currently undergoing instrumental analysis, and will be completed in FY99. The results of these studies will help define the spatial and temporal limits to discriminating fatty acid profiles in important forage species. In FY2000 we will integrate the data from both study years, report findings on the variations of FA and lipids along with their potential use for examining dietary issues in the marine ecosystem.

## NEED FOR THE PROJECT

### A. Statement of the Problem

Trustee sponsored projects including APEX, SEA and NVP focus on understanding trophic relationships, but depend on diet information that does not adequately quantify energy transfer between predator and prey. Diet studies are typically underpowered, because parametric techniques for estimating sample sizes are not well understood (Ferry and Cailliet 1996). Even if

analysis of stomach contents could provide precise estimates of diet over spatial and temporal scales, the data are biased by differences in prey digestibility and the assumption that stomach contents at collection represent diets averaged over time. Marine mammal diets are usually assessed by examining scats, which have many of the same biases as stomach contents. In addition, diet evaluation by stomach or fecal content analysis provides only an indirect method for estimating the amount of energy transferred between predator and prey, since measurements of energy density and digestibility estimate energy availability rather than energy acquisition.

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

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

Systematic development of a trophic relation that can be examined by FA and lipid class analysis requires an examination of the sources of variability in the FA profiles of prey. Essential FA are best identified in controlled feeding trials where the FA composition of the predator can be evaluated over time and related to known changes in the FA composition of its prey. Ideally, feeding trials will survey several developmental stages in the predator since, FA profiles will change in response to ontogenetic demands (Leger 1985). Before validating the assumption that a predator's FA composition reflects its diet, the analysis of FA profiles to examine trophic relationships needs to be extended by understanding how variation in FA composition is structured spatially, temporally, and developmentally. It is important to know if the variation of FA composition within a local aggregate is greater or less than variation between distant aggregates because these sorts of differences provide a basis for statistically identifying

aggregates. Similarly, it is important to know if the variation in FA composition of a fish aggregation sampled at a particular time is greater or less than the variation observed between two times. Also, how does the magnitude of this variation compare with variation in other species. The answers to these questions will demonstrate the utility of FA analysis for examining trophic relationships.
The structure of variation between groups identified *a priori* can be examined with existing multi variate techniques. Once the structure to variation in the FA composition has been described then the plausibility of specific models aimed at hind casting predator diets from the FA composition of its depot fats will be known. Ideally, predator FA profiles would be compared to a library of prey profiles described for the predator' s foraging range, and the relative abundance of each prey item in the predator diet would be predicted with some measure of statistical confidence. Currently Tree Structures (CHART) are used to specify prey compositions in predator diets, but no statistical confidence is associated with the compositions identified by this technique, nor are the relative contributions of the prey predicted. Development of a parametric model for hind casting diet composition must wait until the sources of variation in prey FA profiles are better understood and essential FA identified.

**B. Rationale/Link to Restoration**

We propose to complete our investigation into the spatial and temporal variability of FA profiles and nutritional condition of forage fish. The allocation of consumed and stored energy of forage fish is dependent on the requirements of the organism as dictated by its particular life stage as well as a number of physical environmental factors. Juvenile fish are primarily allocating their energy to growth while mature fish might be allocating energy to gonad production and fish preparing for winter dormancy are building fuel reserves. These allocations might also be influenced by water temperature, physical activity, and prey availability. In FY99 we are analyzing sandlance over a time period that encompasses the period of lipid buildup, energetic allocations, and preparation for reproduction. We will report on how these temporal and developmental changes influence the FA profile and energetic lipid storage of sandlance.

APEX project 163M and 163E proposed to characterize the relationships between seabird populations and forage fish densities. They will benefit from the specific energetic data proposed in this project. These data will provide APEX investigators with valuable information regarding the nutritional value of sandlance in Lower Cook Inlet and PWS. These data will also address questions about the variability of FA profiles posed by Restoration Study 064 (Harbor Seals), and further complement those investigations with increased power to resolve harbor seal diets. Thus, the studies proposed here have direct links to a number of ongoing and proposed projects, and will also provide information that is of interest to other Trustee programs.

A stated objective of the Trustee funded APEX project is to examine the differences in forage fish diets and determine the consequences of the differences at the individual and population level. We propose to supplement the cruder evaluations of energetic content (calorimetry) in herring and sandlance proposed under the APEX studies with analysis of lipid class composition

and FA profiles, since lipid class composition provides a direct measure of the energetic consequences of different diets (Fraser 1987). In this two year project, examination of the FA profiles of herring, sandlance and their prey from PWS and Cook Inlet will quantify the temporal (FY99) and spatial (FY98) range of diet variability because dietary differences are thought to be reflected in FA profiles.

### C. Location

Samples for this project were collected from lower Cook Inlet and central PWS. All the samples have been shipped to and processed in at the NMFS Auke Bay Lab in Juneau, Alaska.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

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

## PROJECT DESIGN

### A. Objectives

The main objectives are to examine of the spatial and temporal ranges of variability in sandlance FA profiles and relate these differences to nutritional condition.

In FY98 we began the examination of spatial variability using samples collected in July, 1997 by APEX investigators. Young of the year herring and sandlance were collected at several locations near Naked Island in central Prince William Sound and at locations near Bainbridge Island in SW Prince William Sound. In addition, the lipid quality and composition of prey fields sampled in these two locations will also be characterized. The FA profiles and lipid class composition of the major zooplankton taxa will be evaluated. These values will be weighted by the relative abundance of these taxa (as estimated by APEX investigators) to model the FA availability in local prey fields. The hypotheses tested with data acquired in FY98 are:

1. FA profiles of herring and sandlance are the same.
2. FA profiles of herring are the same regardless of the presence of sandlance.
3. FA profiles of herring are the same between the central and southern parts of PWS.
4. FA profiles of herring are the same between bays within southern PWS.

Similarly, the zooplankton tows have been analyzed and the following hypotheses tested:

5. Energy is the same between bays within a region
6. Energy is the same between the central and southern regions of PWS

Chemical analyses were begun in FY98 and will be finished in FY99. In FY99 we will also complete statistical analysis of data processed in FY98 on the spatial differences and examine the temporal scales of variability in the FA profiles of sandlance using samples collected by APEX 163M investigators in lower Cook Inlet and APEX 163E investigators in PWS. We plan to relate these temporal changes to the developmental stage of the organism. A timed series of FA profiles from 2 separate locations provides investigators valuable information into how energy allocation is affected by ontogenetic and reproductive changes and if differences are dictated by location as well as ontogeny. Specific FY99 objectives are listed below.

1. Determine how FA profiles change in one location over time and relate those changes to the life stages of adult and juvenile sandlance.

2. Determine if temporal changes are unique to a specific area or if the changes are similar between lower Cook Inlet and PWS.

Herring have not been included in this plan because their broader foraging ranges suggest the probability of consistently sampling a herring aggregate through time is minimal. Sandlance present a low cost solution to this problem.

In FY2000 we propose to complete statistical analysis of data collected in FY99. Multi variate techniques will be used to identify significant differences in FA of samples collected from the same location over a period of time. Initial data (FY98) indicate that FA profiles in forage fish vary spatially and suggest that variation may be highly sensitive to their developmental stage. The analysis of the data collected on temporal scale (FY99) will further investigate how FA vary with the developmental stage of the specimen. Inclusively these analyses will provide insight into the examination of diet composition and nutritional consequences.

**B. Methods**

Temporal and Life Stage Dependent Variations in Sandlance FA Profiles

From May through September, 1998, APEX 163M investigators made biweekly collections of sandlance in lower Cook Inlet near Kachemak Bay. These 10 collections allow us to examine the temporal scale of variability in FA and the variability among larval, juvenile, and adult sandlance FA profiles. These analyses are currently underway. Sampling design and analytical priorities have been contingent on fish availability. Larval and juvenile sandlance have been processed in triplicate as whole body samples. Adult sandlance will also be processed in triplicate and will be dissected resulting in 3 samples per organism - gonads, viscera, and head-on carcass.

To supplement the time scale of FA profiles of sandlance in lower Cook Inlet we collected samples near Eleanor Island in PWS in conjunction with APEX 163E. These collections provide

a replicate observation in the examination of temporal and life stage variations, and also provide a spatial comparison between the FA profiles of sandlance in Cook Inlet and PWS. Again, sampling design and analytical priorities have been contingent on the availability of fish. Adult and juvenile sandlance are being processed as indicated above. To further supplement this study, herring were collected opportunistically near Eleanor Island. These samples will provide an opportunity to compare the FA profiles of herring from one location between years, 1997 and 1998. The analysis of all collections mentioned above are currently underway.
APEX 163M investigators were responsible for the lower Cook Inlet sample collection, storage and shipment to the Auke Bay Lab. APEX 163E augmented sampling in PWS. Fish were stored in airtight containers and labeled with unique sample numbers and codes reflecting the collection location and date.

Lipid Class/FA Analysis

Samples are extracted by methods developed by Folch (1957) and as outlined in Christie (1982). Lipid classification will employ high performance liquid chromatography (HPLC) and evaporative light scattering detection (ELSD) equipped with a stream splitter and an automated integration system. The lipid classes will be separated on a silica based HPLC column; as they elute from the column, each lipid class will be split with one portion being directed to the detector and the other portion being collected for FA analysis. The portion going to the detector will be integrated and the chromatographic data for each lipid class will be quantified by standard calibration curves established by analyzing standards with lipid compositions similar to the sample.

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

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

Statistical analysis

Statistical analysis of the proposed fish collections will use multi variate techniques to measure the similarity between groups classified *a priori.* Groups will classed by age, location and sampling period and their FA compositions will be summarized by discriminant analysis and the distance between group centroids will be measured and tested to determine if they are different from 0. Rejection of a null hypothesis that the distance is 0 indicates significant differences exist between the groups, therefore variation in FA composition within the group is less than variation between the groups. In addition, differences among FA profiles can be related to APEX-generated data on diet diversity, as well as species diversity and energy density of concurrently sampled prey fields.

Differences in nutritional condition between the logically associated groups identified by ordination will be examined by ANOVA. The existence of different logical groups based on differences in FA profiles of the TAG component suggests dietary differences, this analysis will examine the nutritional consequences of these dietary differences. Nutritional condition will be calculated as the proportion of total lipid comprised of TAG. A one way ANOVA will be used to examine differences in the mean nutritional condition between logical groups.

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

The experiments described in this proposal are designed to initiate development of techniques for examining broad scale trophic relationships and supplement other Trustee Projects. In this project we begin by examining the structure of variation in FA composition. We have chosen to examine a forage fish model because of their central value to the PWS ecosystem. APEX 163M and APEX 163E were responsible for sample collection and will benefit from our analysis by relating our measures of dietary differences and their energetic consequences to their coarser indices of nutritional condition.

## SCHEDULE

### A. Measurable Project Tasks for FY2000 (October 1, 1999 - September 30, 2000)

| | |
|---|---|
| October 1, 1999: | Complete chemical analysis of all samples |
| December, 1999: | Complete statistical analysis of data from temporal variability samples. |
| January, 2000: | Report on temporal scales of variability of forage fish FA profiles |
| July, 2000: | Submit Final Report |

### B. Project Milestones and Endpoints

FY00

| | |
|---|---|
| Nov. 1999: | Compile all FA and lipid data in working database. |
| Dec. 1999: | Complete statistical analysis of temporal and life stage data. |
| Jan. 2000: | Report on temporal and life stage variations in forage fish FA profiles. Submit manuscript on spatial variability of FA. |
| April 2000: | Submit manuscript on temporal variability of FA. |
| July 2000: | Submit manuscript on life stage variations of FA. |
| Sept. 2000: | Final Report submitted. |

**C. Completion Date**

This project began in FY98, and will continue through FY00. Chemical analysis of all samples will be complete in FY99. Synthesis of the temporal data will be complete in the first quarter of FY00, and the final report will be submitted in FY00.

**PUBLICATIONS AND REPORTS**

April 1999: Annual Report containing data on the forage fish studies

Jan. 2000: Submit scientific manuscript to journal:
*Heintz, R , M. Larsen, S. D. Rice, and APEX investigator. 1999. Spatial Variation of FA Profiles and Lipid Class Compositions in Herring, Sandlance, and Their Prey in Prince William Sound, Alaska. Journal uncertain.*

April 2000: Submit scientific manuscript to journal:
*Heintz, R, M. Larsen, S. D. Rice, and APEX investigator. 2000. Temporal Variation of FA Profiles and Lipid Class Compositions in Sandlance in Lower Cook Inlet and Prince William Sound, Alaska. Journal uncertain.*

July 2000: Submit scientific manuscript to journal:
*Heintz, R, M. Larsen, S.D. Rice, and APEX investigator. 2000. Life Stage Variation of FA Profiles and Lipid Class Compositions in Sandlance in Lower Cook Inlet, Alaska. Journal uncertain.*

Sept. 2000: Final Report.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

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

## PROPOSED PRINCIPAL INVESTIGATOR

Ron Heintz
National Marine Fisheries Service
11305 Glacier Hwy.
Juneau, AK. 99801
office: 907-789-6058
fax: 907-789-6094
rheintz@abl.afsc.noaa.gov

## PRINCIPAL INVESTIGATOR

Ron Heintz obtained his BS in Ecology, Ethology & Evolution from the University of Illinois in 1979 and his MS Fisheries Science from the University of Alaska in 1986. He has worked for the National Marine Fisheries Service, Auke Bay Laboratory since 1985 and been actively involved with Trustee sponsored research since 1992. He is a co-investigator in two pink salmon studies, the first examines the effects of incubating in oiled gravel on reproductive capacity, and the other examines the effects on homing fidelity. The first of these projects established the plausibility of effects on pink salmon fry observed in the Sound after the EVOS, including the existence of long-term effects on growth, marine survival and reproductive ability. He was also a co-author of the final report for Subtidal 8, which examined all of the Trustee Hydrocarbon data for the presence of EVO. This work is of substantial importance to the trustees, by providing evidence for the presence of oil on the beaches of PWS. His efforts in this project led to a detailed understanding of the utility of multi variate methods for analyzing GC/MS data.

## OTHER PERSONNEL

Stanley D. Rice, GM-14 Physiologist
Education:
BA in biology (1966) from Chico State University
MA in biology (1968) from Chico State University
Ph.D. in comparative physiology (1971) from Kent State University

Experience:
1986 - present: Habitat Program Manager. Managed NOAA/NMFS/Auke Bay Laboratory=s *Exxon Valdez* damage assessment and restoration studies. Conducted and managed cooperative projects interactive with other agencies, provided critical reviews and input in agency decisions.
1971 - 1986: Research Physiologist/Task Leader. Researched and managed studies investigating oil effects encompassing a wide variety of organisms and conditions.

Marie Larsen, GS-11 Research Chemist
Education:
BA in chemistry (1983) from The College of St. Benedict

Experience:
1990 - present: Research Chemist. Managed daily activities and schedules in the hydrocarbon analysis lab at the Auke Bay Laboratory. Primary operator of mass spectrometer.
1983- 1990: Contracted chemist services to the U.S. EPA Environmental Research Laboratory-Duluth as part of the National Dioxin Study. Responsibilities included sample processing and operation/maintenance of mass spectrometry systems.

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blubber fatty acids of the male harbour porpoise (*Phocoena phocoena).* J. Comp. Physiol. B. 165:628-639.

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**2000 EXXON VALDEZ TRUS DUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FFY 1999 | Proposed FFY 2000 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Personnel | $57.2 | $34.9 | | | | | | |
| Travel | $6.6 | $4.6 | | | | | | |
| Contractual | $5.0 | $0.0 | | | | | | |
| Commodities | $14.9 | $0.0 | | | | | | |
| Equipment | $0.0 | $0.0 | | | | | | |
| Subtotal | $83.7 | $39.5 | Estimated FFY 2001 | Estimated FFY 2001 | Estimated FFY 2003 | Estimated FFY 2004 | Estimated FFY 2005 | |
| General Administration | $8.9 | $5.2 | | | | | | |
| Project Total | $92.6 | $44.7 | $0.0 | $0.0 | $0.0 | $0.0 | $0.0 | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.4 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | $28.6 | | | | | | |

NOAA Contribution:

Habitat Investigation Program Manager, S. Rice,0.5 mo = $6.1K, Principle Investigator, R. Heintz 1.5 mo @11.1K, Senior Analytical Chemist, M.
Larsen 1.0 mo @ 6.7K, Senior Research Chemist, J. Short 0.5 mo. @ 4.7K for a total NOAA contribution of 28.6K.

**FY00**

Project Number: 00347
Project Title: Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Compostion and Quality at Different Trophic Levels
Agency: National Oceanic & Atmospheric Administration

**FORM 3A TRUSTEE AGENCY SUMMARY**



Prepared: 4/8/99

**2000 EXXON VALDEZ TRUS IUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FFY 1999 |
| R Heintz | Co-PI: Fishery Research Biologist | 12/3 | 2.0 | 7.4 | | 14.8 |
| M. Larsen | Co -PI: Analytical Chemist | 11/7 | 2.0 | 6.7 | | 13.4 |
| L. Holland | Research Chemist | 11/7 | 1.0 | 6.7 | | 6.7 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 5.0 | 20.8 | 0.0 | |
| | | | | | Personnel Total | $34.9 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FFY 1999 |
| Anchorage , EVOS Symposium, 1 | 0.5 | 1 | 4 | 0.2 | 1.3 |
| Miscellaneous (Car rental, telephone chgs, POV mileage, etc.) | | | | | 0.4 |
| | | | | | 0.0 |
| International Fish Symposium, 1 | 1.0 | 1 | 3 | 0.2 | 1.6 |
| Miscellaneous (Car rental, telephone chgs, POV mileage, etc.) | | | | | 0.2 |
| | | | | | 0.0 |
| Chemical Analysis Workshop, 1 | 0.5 | 1 | 2 | 0.2 | 0.9 |
| Miscellaneous (Car rental, telephone chgs, POV mileage, etc.) | | | | | 0.2 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | Travel Total | $4.6 |

**FY00**

Project Number: 00347
Project Title: Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Compostion and Quality at Different Trophic Levels
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Personnel
& Travel
DETAIL



Prepared: 4/8/99

**2000 EXXON VALDEZ TRUS )UNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FFY 2000 |
| | 0.0 |
| | 0.0 |
| | 0.0 |
| | 0.0 |
| | 0.0 |
| | 0.0 |
| | 0.0 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $0.0 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FFY 2000 |
| **Commodities Total** | $0.0 |

**FY00**

Project Number: 00347
Project Title: Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Composition and Quality at Different Trophic Levels
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Contractual & Commodities DETAIL



Prepared: 4/8/99

**2000 EXXON VALDEZ TRUS )UNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FFY 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 |
| 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 |
|---|---|---|
| Computer | 1 | |
| GC/MS | 1 | |
| HPLC | 1 | |

**FY00**

Project Number: 00347
Project Title: Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Compostion and Quality at Different Trophic Levels
Agency: National Oceanic & Atmospheric Administration

**FORM 3B Equipment DETAIL**



Prepared: 4/8/99

# Responses of river otters to oil contamination: a controlled study of biological stress markers

| | |
|---|---|
| Project Number: | 00348 |
| Restoration category: | Research |
| Proposers: | Merav Ben-David<br>R. Terry Bowyer<br>Lawrence K. Duffy<br>University of Alaska Fairbanks |
| Lead Trustee Agency: | ADF&G |
| Cooperating Agencies: | NOAA; Purdue University, Indiana; Woods Hole Oceanographic Institute. |
| Alaska SeaLife Center: | No |
| Duration: | 3rd year, 3 year project |
| Cost FY00: | $66,100 |
| Cost FY01: | None |
| Cost FY02: | None |
| Geographic Area: | Prince William Sound and Fairbanks, Alaska. |
| Injured Resource: | River otters - Recovered. |


## ABSTRACT

This project was designed to explore experimentally the effects of oil contamination on physiological responses in river otters (*Lutra canadensis*). Fifteen captive otters were exposed to two levels of oil contamination under controlled conditions, at the Alaska SeaLife Center in Seward. Samples of blood, tissues and feces were collected for analysis of biomarkers, and immunological examinations. A wealth of data was collected during the experiment phase. Completion of data analyses and report preparation of these controlled experiments is especially important in light of the recent listing by the *EVOS* Trustee Council of river otters as a recovered species.

## INTRODUCTION

In this proposal funding is requested for completion of analyses and report writing for the project "Responses of river otters to oil contamination: a controlled study of biological stress markers". This project originated from the need to better understand the effects of contamination by crude oil on biological stress markers in river otters (*Lutra canadensis*). Previous studies demonstrated elevated levels of biological stress markers (bioindicators) in river otters from oiled areas compared with those from nonoiled areas throughout Prince William Sound, Alaska, shortly following the *Exxon Valdez Oil Spill* (*EVOS*). Although the field data collected to date strongly indicated a correlation between oil contamination and physiological stress in river otters, this circumstantial evidence required verification through controlled experiments as identified by the *EVOS* Trustees Council review process (1997). Also, it was difficult to assess from the field evidence whether the physiological stress is a direct result of oiling or a secondary response to food limitation (Fig. 1). Completion of analyses and report writing of data collected in these controlled experiments is especially important, in light of the recent listing by the *EVOS* Trustee Council of river otters as a recovered species.

### Background

*General*

Investigations in Prince William Sound following the *Exxon Valdez* oil spill revealed that river otters (*Lutra canadensis*) on oiled shores had lower body mass and elevated levels of bioindicators, than did otters living on nonoiled shores (Blajeski et al., 1996; Duffy et al. 1993; 1994a; 1994b; 1996). In addition, otters from oiled areas selected different habitat characters, had larger home ranges, and less diverse diets than those in nonoiled areas (Bowyer et al. 1994; Bowyer et al. 1995). These observed differences between river otters from oiled shores and those from nonoiled areas strongly suggest that oil contamination had an effect on physiological and behavioral processes in otters. Although the field data collected to date strongly indicated a correlation between oil contamination and physiological stress in river otters, this circumstantial evidence required verification through controlled experiments.

*Biomarkers*

Studies initiated following the *EVOS* suggest that several mammalian and avian predators display physiological stress related to oil toxicity. Sea otters from oiled regions had greater antigenic stimulation than animals from unoiled areas (Rebar et al., 1994). Pigeon guillemots had elevated levels of haptoglobins and blood proteins in specific locations and years, although dosing experiments in the field failed to demonstrate the connection between oiling and those parameters (Prichard et al., 1997). More specifically, river otters live-captured in oiled areas had higher haptoglobin, Interleukin - 6 (Il-6), and fecal porphyrin levels than otters from nonoiled regions post spill (Blajeski et al., 1996; Duffy et al., 1993; 1994). In addition, river otters showed elevated haptoglobin and P450 values in 1996 (G. M. Blundell, pers. comm.). Similar changes in plasma proteins, abnormalities in white blood cells (leukocytes), reduction in the number of red blood cells (erythrocytes), and electrolyte imbalance, were observed in mink (*Mustela vison*), and polar bears (*Ursus maritimus*) following exposure to hydrocarbons (Mohn and Nordstoga, 1975; Oristsland et al., 1981; J. Mazet, UC Davis, personal communication).

Cytochrome P450 are a group of enzymes that metabolize a wide variety of xenobiotic compounds. P450-1A is specifically induced by planar aromatic or chlorinated hydrocarbons, and thus its presence serves as a bioindicator of hydrocarbon exposure. Haptoglobin and Il-6 indicate increase liver activity in synthesizing acute-phase proteins in response to tissue injury (Duffy et al., 1993; 1994). Porphyrins are tetrapyrrolic pigments that are involved in biosynthesis of the heam molecule. Chemical-induced changes in patterns of porphyrins have been observed in several avian species following an exposure to aromatic hydrocarbons (Miranda et al., 1987).

*Work conducted to date*

Fifteen wild male river otters were live-captured in Northwestern PWS using No. 11 Sleepy Creek leg-hold traps under permit from the Alaska Department of Fish and Game (98-001). Traps were placed on trails at latrine sites and monitored by trap transmitters (Telonics, Mesa, Arizona, USA) that signal when a trap is sprung. Processing of otters began within 1 - 2 hours from capture. Otters were anesthetized with Telazol (9mg/kg; A. H. Robins, Richmond, Virginia, USA) administered using Telinject darts and a blowgun. Blood and tissues were sampled from each individual otter at that time.

The fifteen wild-caught male river otters were transferred under sedation via air to the Alaska SeaLife Center in Seward, Alaska. The otters were held in captivity at ASLC from May 1998 to March 1999. The animals were housed as one large group in an area of 90 $m^2$ surrounding 6 pools:

1. 1 large salt-water pool (4.5 m diameter x 3 m depth).
2. 4 small salt-water pools (2 x 1.5 x 1.5 m).
3. 1 small fresh-water pools (1 x 1x 1m).

Otters were fed frozen fish on a daily basis and diet was supplemented with live prey, vitamins, and minerals.

Experiments began in August allowing the animals 2.5 months to acclimate to the enclosure, feeding regimes, and handling (Fig. 2). After the acclimation period, otters were randomly assigned to 3 experimental groups of 5 individuals each:

Group 1 - control
Group 2 - exposure to low levels of oil (100 ppm)
Group 3 - exposure to high levels of oil (1000 ppm)

Weathered (comparable to 2 weeks weathering) Prudhoe Bay Crude oil was administered to otters in gel capsules hidden in fish. Oil feeding lasted 100 days from August 21 to November 28, 1998. Data collection continued for 100 additional days of rehabilitation.

Prior to the exposure to oil (August 1998), a series of tissue sampling (Table 1) was conducted on each individual otter. Tissue sampling continued from August 15,1998 until February 24, 1999 every three weeks.

Table 1. - Tissues collected for bioindicator analyses from oiled and nonoiled captive otters at the Alaska SeaLife Center August 1998 – February 1999.

| Bioindicator analysis | Tissue | Number of samples |
|---|---|---|
| Haptoglobin | Blood serum | 150 |
| IL-6 | Blood serum | 150 |
| Other liver enzymes (AST, ALT, GGT, LD, etc.) | Blood serum | 150 |
| P450-1A1 | Skin punch | 75 |
| P450-1A1 | Lymphocytes | 135 |
| Immune function assays | Lymphocytes | 135 |
| CBC | Blood cells | 150 |
| Serum Chemistry | Blood serum | 150 |
| Fecal porphyrins | Feces | 150 |

Otters were implanted with radio-transmitters (IMP/400, Telonics, Meza, Arizona) on February 22 – 24, 1999. Otters were allowed to recover from surgery for 3 weeks. Release occurred on the week of March 14, 1999 at the location of the initial capture. Radio tracking of otters to determine post-release survival began immediately following release and will last until March 2000.

*Preliminary results*

We were able to document the occurrence of anemia (Fig. 3) and elevation in several liver enzymes in oiled river otters compared with nonoiled otters in our experiment. Analyses for other bioindicators will be completed by September 1999. Skin punch samples were sent to Woods Hole Oceanographic Institute (Dr. John Stegeman) in January 1999. Lymphocytes, blood smears, bone marrow extracts, and blood serum samples were sent to Purdue University (Drs. Alan Rebar and Paul Snyder) in March 1999. Blood serum and fecal samples were sent to Fairbanks (Dr. Larry Duffy) in January 1999.

*Related experiments*

During the experiments listed above several related questions and hypotheses that required additional testing became relevant:

- Studies conducted on mink (R. G. White, IAB – UAF, pers. comm.) suggested that consumption of oil increased passage rate of food in the gut. Such increased passage rate may have a negative effect of assimilation efficiency of diet and cause reduction in body condition of free ranging wildlife. In addition, increased passage rate may reduce assimilation of ingested oil resulting in a lower exposure to oil than predicted during the dosing experiments. To test these hypotheses we fed the oiled and nonoiled river otters with color beads and collected feces every half an hour for 5 days. Passage rate will be calculated from occurrence of colored beads in the feces using the following formula:

  $$\text{TMRT (Total mean retention time)} = \int t.SR.dt \,/\, \int SR.dt$$

  Where SR is number of beads in feces and t is time.
  Assimilation efficiency of diet and assimilation of hydrocarbons from feces will be determined using Stable Isotope Analysis.

- During the feeding of oil two different batches of oil, provided by Alyeska Pipeline and weathered at the Alaska SeaLife Center, were used. Preliminary results suggested that otters responded differently to the two batches. A full hydrocarbon profile of the 2 batches of weathered oil may assist in isolating the compounds responsible for the different responses by otters. Analysis of hydrocarbon profiles will be conducted at the Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA.
- Diet of river otters from oiled shores was significantly different than that of otters from unoiled areas (Bowyer et al., 1994). Surveys of intertidal organisms in Prince William Sound, suggested that species composition and biomass of subtidal fishes did not differ between oiled and nonoiled areas (Thomas Dean, pers. comm.). In addition, diets of otters along oiled shores were more similar to the species composition of subtidal fish than that of otters from nonoiled shores (Bowyer et al. 1994; Thomas Dean, pers. comm.) suggesting that otters on oiled shores differed in their foraging strategies from otters on nonoiled areas. Kruuk et al. (1990) demonstrated that foraging success of European river otters (*Lutra lutra*) in marine environments in Shetland, was determined largely by behavior of both prey and predators. Foraging behavior of semi-aquatic mammals such as river otters will be partially determined by their diving ability. For mink (*Mustela vison*), several studies have shown that the relatively small surface of their feet, their anterior propulsion, and their low storage capacity for $O_2$ make them an inefficient swimmer compared with other diving mammals (Ben-David et al., 1996; Dunstone and O'Connor 1979*a*; 1979*b*; Stephenson et al. 1988; Williams 1983; 1989; Williams and Kooyman 1985). Although river otters have a higher surface-area of feet, higher storage capacity for $O_2$, and better propulsion capabilities (Fish, 1994; Tarasoff et al., 1972), these limitation on swimming and diving efficiency could affect the duration and depth of dives especially in sea water, which has higher density and viscosity than does fresh water (Vogel 1981). Exposure to oil, associated chronic physiological stress, and reduction in numbers of red blood cells (i.e. lowered $O_2$ storage capacity; Oritsland et al., 1981) could have an affect on the diving ability of otters (see Fig. 1). The diet of otters in oiled areas in PWS was largely composed of sessile subtidal fish that are easier to catch. Therefore, the physiological stress imposed on oiled otters may have resulted in the observed differences in diet between otters in oiled and nonoiled areas (Bowyer et al. 1994).

  The observed anemia as a result of the controlled oiling experiments suggested that diving ability and thus foraging success of river otters may be compromised. To test these hypotheses otters were offered 2 types of live fish in the large salt-water pool: schooling fast fish and slow intertidal fish. Dive duration, recovery times, and capture success were recorded for each individual otter. Each session was also videotaped and data on diving speeds and acceleration rates will be extracted. Diving experiments were conducted prior to oiling (August 1998), at the height of oiling (November 1998) and at the end of rehabilitation period (February 1999). In addition, oxygen consumption under exercise was measured for oiled and nonoiled otters at the height of oiling (October 1998) using a treadmill and a metabolic chamber. Preliminary results suggest a trend for longer recovery times for oiled otters as well as a trend for higher levels of consumed oxygen for oiled animals.
- Data from the NVP 1996 and 1997 field seasons indicated a possible relation between testosterone levels and scores of P450-1A1 in skin punches collected form wild river otters (G. M. Blundell, pres. Comm.). To clarify the relation between testosterone and P450-1A1, plasma samples were collected for each individual during each session of blood drawing. Also, data on other parameters that may be related to levels of testosterone such as testicle size, and social dominance were recorded.

- Because P450-1A is specifically induced by planar aromatic or chlorinated hydrocarbons, it will be important to determined the levels of PCB in tissues of oiled and nonoiled river otters. Because PCBs in vertebrates usually accumulate in fat tissues, fat samples were collected from each individual otter during the implant surgeries.
- Little data exist to date on post-release survival of rehabilitated oiled wildlife (DeGrange et al., 1995). Large sums of money are spent on rehabilitation following oil spills, but little monitoring of post-release survival has been done (Goldsworthy et al., 1997; Sharp 1996). This study provides a unique opportunity to obtain such critical data because five of the fifteen individuals were not exposed to oil. Therefore, this study design will assist in partitioning the effects of exposure to oil on post-release survival from the effects of captivity itself on survival, which can not be done with regular rehabilitation studies. We are seeking additional funding for radio tracking from other agencies and foundations.

## NEED FOR THE PROJECT

### A. Statement of Problem

The 1997 review process of the NVP Project funded by the *EVOS* Trustee Council identified the need to verify the effects of oil contamination on physiological stress responses in river otters. Data collected in summer 1996 revealed that coastal river otters in the western Prince William Sound, were still exposed to oil contamination (P450) and showed high levels of haptoglobins. None of these differences were detected in 1997 and 1998 field seasons. The latter led the *EVOS* Trustee Council to change the listing of otters from "recovering" to "recovered". Nonetheless, completing analyses and report writing of data collected in the captive experiments is crucial for the interpretation of the results obtained in the field and the affirmation of the new listing of river otters in Prince William Sound.

### B. Rationale/Link to Restoration

Effective implementation of the *EVOS* Trustee Council's policy that "Restoration should contribute to a healthy, productive and biologically diverse ecosystem...", is complicated by the diversity and trophic interdependence of the numerous injured resources within the nearshore system. The existing evidence of chronic physiological stress in a wide variety of nearshore vertebrate predators (see NVP project) requires verification under controlled experiments, before the mechanisms that constrain recovery can be understood.

### C. Location

Radio tracking will be conducted in Prince William Sound. Stable isotope and testosterone analyses, will be conducted at the University of Alaska Fairbanks. Hydrocarbon profiles will be conducted at the Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, Juneau. Report writing will be done at the University of Alaska Fairbanks.

## COMMUNITY INVOLVEMENT

This project involved intensive data collection both in the 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. The captive river otters in the SeaLife Center were available for public viewing and education. We have participated in the development of the educational materials associated with the river otter display, including an interactive exhibit (i.e., kiosk) that will be continuously displayed at the Center in the future. This exhibit will also include a live-update on the survival of the otters in the wild, obtained from the radio tracking. We have interacted with local communities and presented our findings to community members and the general public. Additional presentations will be organized through the SeaLife Center. The radio tracking will be conducted by a local air service.

## PROJECT DESIGN

### A. Objectives

The general objective of this study is to document the effects of exposure to oil on physiology and behavior of river otters under controlled conditions. In this study, we have addressed the following main hypotheses:

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

Additional relevant questions and hypotheses were tested as a result of the information gathered to address the main hypotheses (see Introduction - related experiments section).

The objectives for FY00 are to complete the following analyses, manuscript writing, and publication of results:

1. Stable isotope analysis for determination of assimilation efficiency of diet and assimilation of ingested hydrocarbons.
2. Testosterone analysis for determination of the relation between testosterone and P450-1A1 levels.
3. Hydrocarbon profile analysis of 2 batches of weathered oil to assist in isolating the compounds responsible for the different responses by otters.
4. PCB analysis for fat tissues for evaluating the possibility of PCB contamination.
5. Complete aerial telemetry for survival estimates.

### B. Methods

*Stable Isotope analysis*

Fecal samples are kept frozen until preparation for determination of stable isotope ratios. Samples will be dried at 60° to 70° C for 48 hours and then ground to fine powder using a Wig - L - Bug grinder (Cresent Dental Co.). Subsequently, a sub-sample of 1-1.5 mg will be weighed into a miniature tin cup (4 by 6 mm) for combustion. We will use a Europa C/N continuous flow isotope ratio mass spectrometer (CFIRMS) to obtain the stable isotope ratios. Each sample will

analyzed in duplicate and results will be accepted only if the variance between the duplicates will not exceed that of the peptone standard
($\delta^{13}C_{std}$ = -15.8, $\delta^{15}N_{std}$ = 7.0, CV = 0.1). Assimilation efficiency of diet will be calculated based on %N and $\delta^{15}N$ values using a mixing model (Ben-David et al., 1997). Assimilation of hydrocarbon will be calculated based on $\delta^{13}C$ values (Ben-David, unpub. Data).

*Testosterone analysis*

Testosterone assays on plasma will be done using Diagnostic Products iodinated solid-phase RIA kit (Dr. J. Rowell, University of Alaska Fairbanks). Intra- and inter-sample variation will be calculated.

*Hydrocarbon profile analysis*

PAH analysis utilizes dichloromethane extractions of the hydrocarbons spiked with a suite of deuterated surrogate standards, followed by fractionation and purification by alumina/silica gel chromatography. PAH samples are further purified by size-exclusion HPLC. PAH are measured by gas chromatography/mass spectrometry (GC/MS) in the
selected ion monitoring mode (SIM). Aliphatic hydrocarbons are separated and measured by gas chromatography/flame ionization detection. These methods are more completely described By Short et al., 1996.

*PCB analysis*

PCB analysis will be conducted using the 80-82 method using a GC masspectrometer and will be contracted to a private company in Anchorage.

*Aerial telemetry*

Monitoring by Aerial telemetry of animal locations will be done using a fixed-winged aircraft and a GPS unit. Location, movements, and fate will begin the week of March 14 and will be done on a weekly basis until the end of April (e.g., 6 flights). After the end of April monitoring flights will be scheduled every second week until early March 2000.
Survival will be calculated using a Kaplan-Meier estimator (Johnson, 1994) and differences between the groups (i.e., control, low dose, and high dose) will be established using a Kruskal-Wallis test (Zar, 1984)

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

This project is a collaborative research project of scientists from a variety of state (ADFG), university, and private research centers. University of Alaska Fairbanks will be responsible for the research work order, and contracts to Auk Bay Laboratory.
Radio tracking aircraft will be chartered from the private sector.

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

Additional funding for radio tracking was requested from Oiled Wildlife Care Network, University of California, Davis, and Oil Spill Recovery Institute, Cordova, Alaska.

## SCHEDULE

### A. Measurable tasks for FY 00.

This project began in 1998 and will be completed in 2000.

October – December 1999: Complete lab analyses
October 1999 – March 2000: complete radio tracking
January 18-28 (3 of these days): Attend Annual Restoration Workshop
January – June 2000: complete writing of manuscripts and submit for publication
August 2000: Attend the meeting of the Wildlife Diseases Association.
September 2000: Attend the Wildlife Society meeting

### B. Project milestones and endpoints

FY 98: Data collection
FY 99: Data collection and submission of 3 manuscripts
FY00: Completion of lab analyses and submission of 5 manuscripts

### C. Completion Date

The work will be completed by Sept. 2000.

## PUBLICATIONS AND REPORTS

Publications to be submitted by September 30 1999:

1. Title: Responses of river otters to oil contamination: a controlled study of biological stress markers
   Authors: M. Ben-David, L. K. Duffy, R.T. Bowyer, and A. Rebar
   Description: manuscript will present and discuss data on effects of oiling on serum chemistry, CBC, haptoglobins and IL-6 values.
   Journal: Journal of Wildlife Diseases

2. Title: P450-1A1 expression in oiled and nonoiled river otters: evaluating 2 methods.
   Authors: M. Ben-David, P. W. Snyder, J. Stegeman, L. K. Duffy, and R.T. Bowyer
   Description: manuscript will present and discuss data on effects of oiling on P450-1A1 levels in lymphocytes and skin punches of oiled and non-oiled river otters.
   Journal:

3. Title: Effects of oiling on exercise physiology and diving ability of river otters: a controlled study.
   Authors: M. Ben-David, T. M. Williams, O. A. Ormseth
   Description: manuscript will present and discuss data on effects of oiling on oxygen consumption, duration of diving and recovery of oiled and nonoiled river otters.
   Journal: Journal of Experimental Biology.

Publications to be submitted by September 30, 2000:

4. Title: Responses of river otters to oil contamination: fecal porphyrins.
   Authors: C. Taylor, L. K. Duffy, and M. Ben-David
   Description: manuscript will present and discuss data on occurrence of porphyrins in feces of oiled and nonoiled captive river otters. Implications for field use of this biomarker will be discussed.
   Journal: Journal of Physiology.

5. Title: Passage rate and assimilation efficiency in river otters: effects of oil ingestion.
   Authors: O. A. Ormseth and M. Ben-David
   Description: manuscript will present and discuss data on passage rate and assimilation efficiency of oiled and nonoiled river otters. In addition, data on assimilation of ingested oil will be presented and implications to the biomarker responses will be discussed.
   Journal: Journal of Physiology.

6. Title: Post-release survival of river otters: effects of oiling or captivity?
   Authors: M. Ben-David
   Description: manuscript will present survival data obtained through radio tracking of released otters. Evaluation of the separate effects of captivity vs captivity plus oiling will be presented.
   Journal: Journal of Mammalogy.

7. Title: Testosterone and P450 in captive river otters: effects of oiling, dominance hierarchy, and season.
   Authors: M. Ben-David, P. W. Snyder, and J. Rowell
   Description: manuscript will present and discuss data on levels of P450 in relation to levels of testosterone in river otters exposed to hydrocarbons. Data will be investigated in light of levels of oil ingested, dominance hierarchy established through behavioral observations and season.
   Journal:

8. Title: Exercise physiology of captive river otters: relating swimming speeds and accelerations to duration of dives and oxygen consumption.
   Authors: T. M. Williams and M. Ben-David
   Description: manuscript will present and discuss data on effects of swimming speeds, and accelerations, on duration of dives and oxygen consumption in captive river otters.
   Journal: Journal of Zoology, London.

Other publications resulting from this project:

9. Title: Group living in coastal river otters: a tradeoff between foraging success and reproductive opportunities.
   Authors: M. Ben-David, G. M. Blundell, and R. T. Bowyer
   Description: manuscript will present and discuss data on effects of group size and fish type on foraging success of captive and wild river otters. In addition, data on reproductive success from DNA fingerprinting and data on spatial distribution of wild otters from radio-telemetry will be presented.
   Journal: Science

10. Title: Group forming in multi-male river otter aggregations: are social interactions dependent on geographic origin or genetic relatedness?
    Authors: M. Ben-David, P. Groves, and O. A. Ormseth
    Description: manuscript will present and discuss data on effects of geographical origin and relatedness, as determined from DNA fingerprinting, on social interactions of captive male river otters.
    Journal: Behavioral Ecology

11. Title: Effects of social interactions prior to release on group cohesiveness of newly freed river otters.
    Authors: M. Ben-David
    Description: manuscript will present and discuss data on effects of social interactions of captive male river otters on their post-release relations.
    Journal: Animal Behaviour

12. Title: Dynamics of weight change in captive river otters: effects of diet quality, diet quantity, and season.
    Authors: M. Ben-David and O. A. Ormseth
    Description: manuscript will present and discuss data on changes in body weight of captive river otters in relation to food consumption and season.
    Journal: Zoo Biology.

13. Title: Fecal deposition in captive river otters: effects of food consumption and activity level.
    Authors: M. Ben-David and H. Golden
    Description: manuscript will present and discuss data on fecal deposition rates of captive river otters in relation to food consumption and activity levels throughout the year. Evaluation of the validity of fecal counts at otter latrine-sites, as a reliable estimate of population levels, will be presented.
    Journal: Journal of Wildlife Management.

14. Title: Scent marking by North American river otters: territoriality, reproductive status, or intra-group communication?
    Authors: R. Rostein and M. Ben-David
    Description: manuscript will present and discuss data on responses of captive river otters to scent of unfamiliar male and female otters, as well as data on their responses to scent of familiar and unfamiliar male otters.
    Journal: Behavioral Ecology.

15. Title: Estimating body condition of river otters: a comparison of BIA, single labeled water ($D_2O$), and weight/length ratio approaches.
    Authors: M. Ben-David and P. Barboza
    Description: manuscript will present and discuss data on estimates of body condition in river otters using 3 methods. Evaluation of the techniques and their usefulness for field studies will be presented.
    Journal: Journal of Wildlife Management.

16. Title: Effects of Telazol™ on body temperature, circulating $O_2$ levels, and pulse rate in captive river otters.
    Authors: M. Ben-David and P. Toumi
    Description: manuscript will present and discuss data on the effects of Telazol™ on body temperature, circulating $O_2$ levels, and pulse rate in captive river otters.
    Journal: Journal of Wildlife Management.

17. Title: Occurrence and treatment of foot infections in captive river otters.
    Authors: M. Ben-David and P. Toumi
    Description: manuscript will present and discuss data on occurrence and treatment of foot infections in captive river otters.
    Journal: Zoo Biology.

18. Title: Occurrence of intestinal parasites in captive river otters fed live fish.
    Authors: M. Ben-David and P. Toumi
    Description: manuscript will present and discuss data on occurrence of intestinal parasites in captive river otters fed live fish.
    Journal: Zoo Biology.

19. Title: Severe anemia in river otters in response to treatment with Ibuprofen.
    Authors: M. Ben-David and P. Toumi
    Description: manuscript will present and discuss data on occurrence of severe anemia in river otters, in response to treatment with Ibuprofen.
    Journal: Zoo Biology.

20. Title: Occurrence and treatment of infected skin wounds in captive river otters, in response to administration of anesthetics, using a blowgun.
    Authors: M. Ben-David and P. Toumi
    Description: manuscript will present and discuss data on occurrence and treatment of infected skin wounds in captive river otters in response to administration of anesthetics using a blowgun.
    Journal: Wildlife Society Bulletin.

21. Title: Determining diet of river otters from stable isotope analysis: validating the technique using captive animals fed known diets.
    Authors: M. Ben-David
    Description: manuscript will present stable isotope data of hair and feces of captive otters and relate these values to those of known food items.
    Journal: Journal of Biogeochemistry.

## PROFESSIONAL CONFERENCES

The senior scientists on this project will present project results at various forums in 2000. However, other than the annual *EVOS* meeting in January in Anchorage, an Environmental Toxicology meeting, and The Wildlife Society meeting.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The project is closely linked with the river otter section of the NVP project and with the SeaLife Center in Seward. The field component of this project has been fully integrated with the NVP project. The NVP project provided additional funding for chartering the vessel that was used to capture the otters. Also NVP personnel joined us in the capture work and assisted with blood drawing and surgeries for transmitter implanting. The costs of analyzing the blood samples from the field captures were incurred by the NVP project. In the SeaLife Center, we (i.e., lead-PI and research technician) have joined the educational team and presented the project to a multitude of visitors, school classes, and the media. Also, we have participated in the development of the educational materials associated with the river otter display, including an interactive exhibit (i.e., kiosk) that will be continuously displayed at the Center in the future. This exhibit will also include a live-update on the survival of the otters in the wild, obtained from the radio tracking. Additional funding for radio tracking was requested from Oiled Wildlife Care Network, University of California, Davis, and Oil Spill Recovery Institute, Cordova, Alaska.

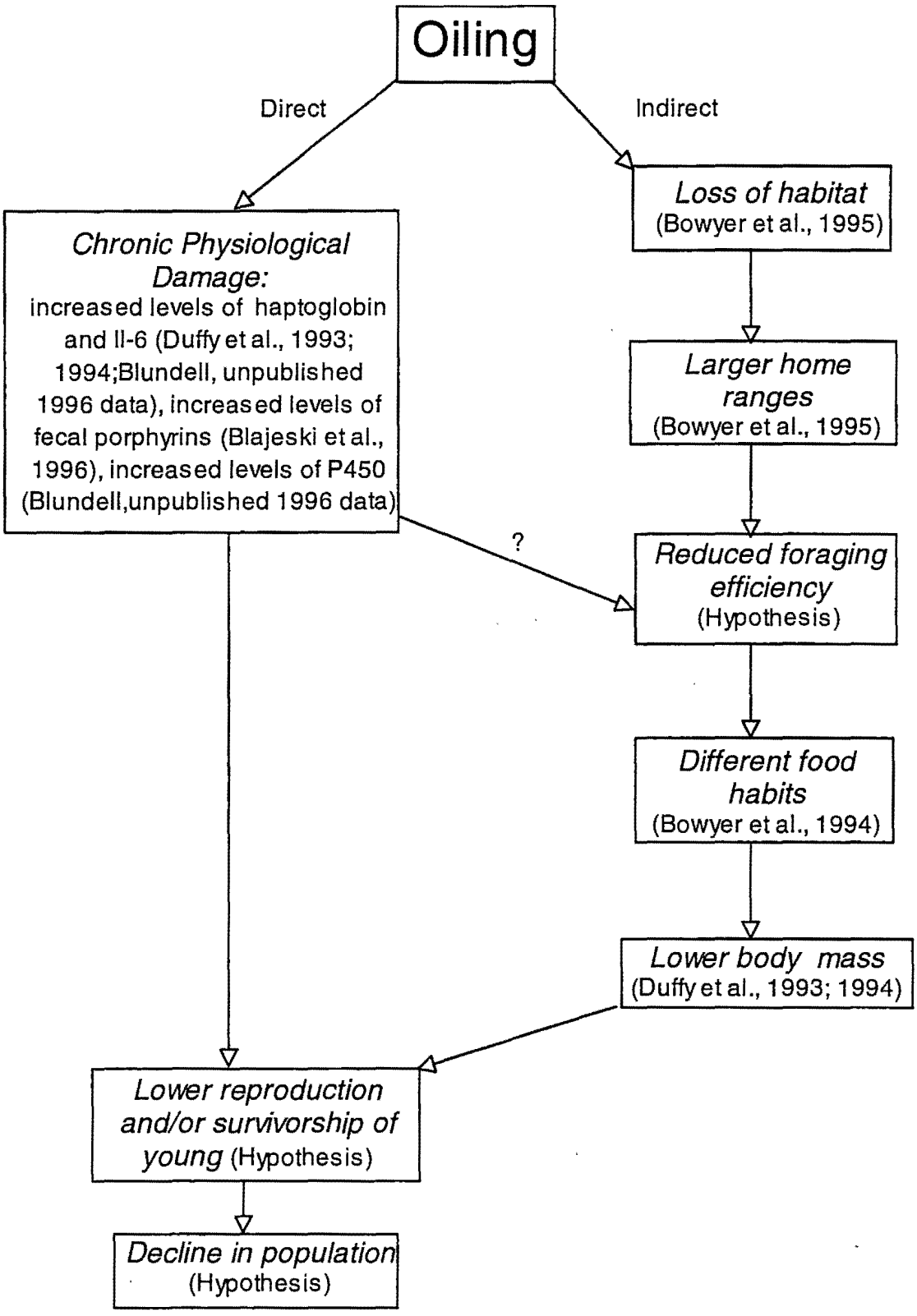


Fig. 1 - Possible pathways for the effect of oiling on river otters in Prince William Sound, Alaska

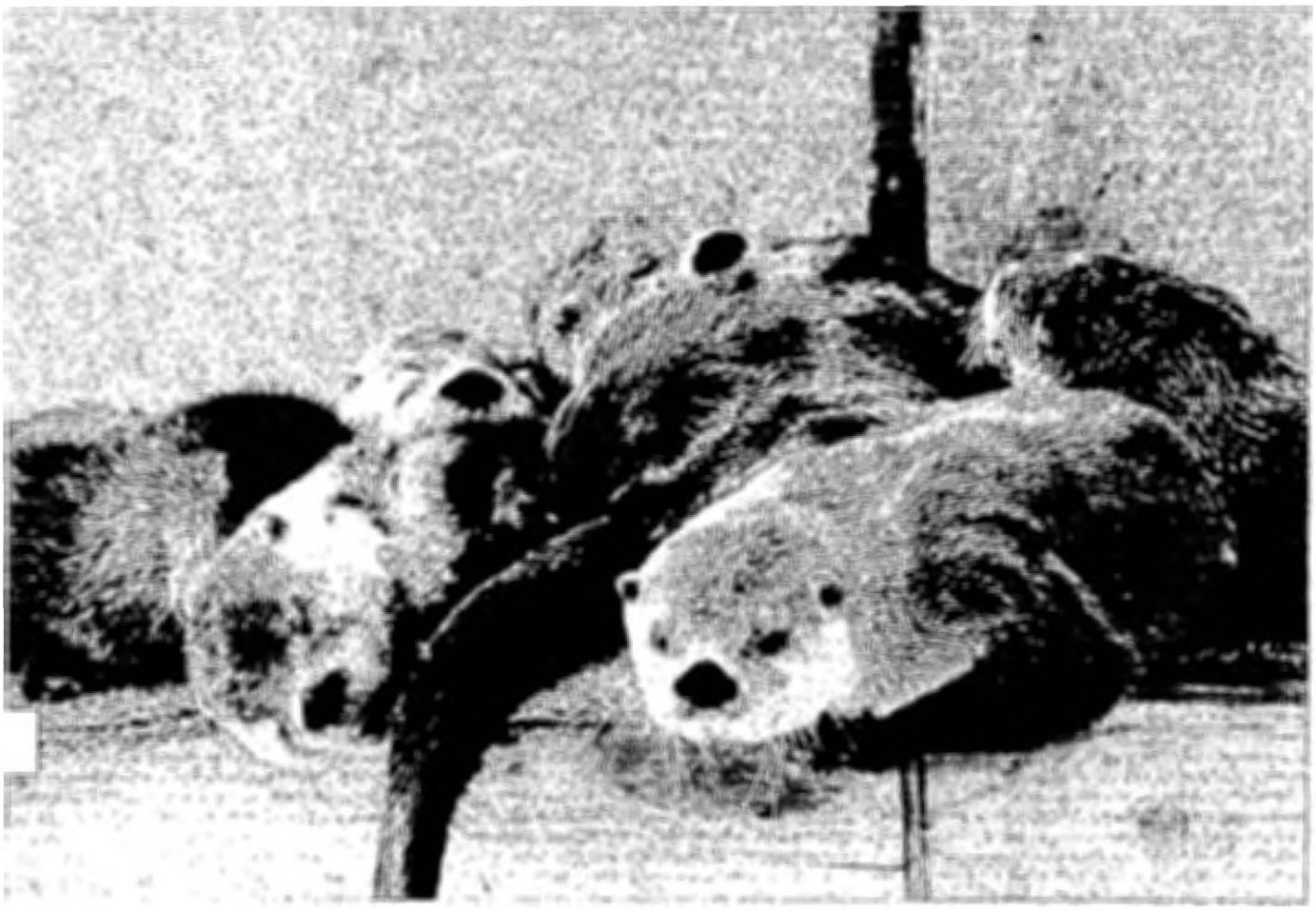

Fig. 2 – A group of river otters at the Alaska SeaLife Center in Seward, Summer 1998.

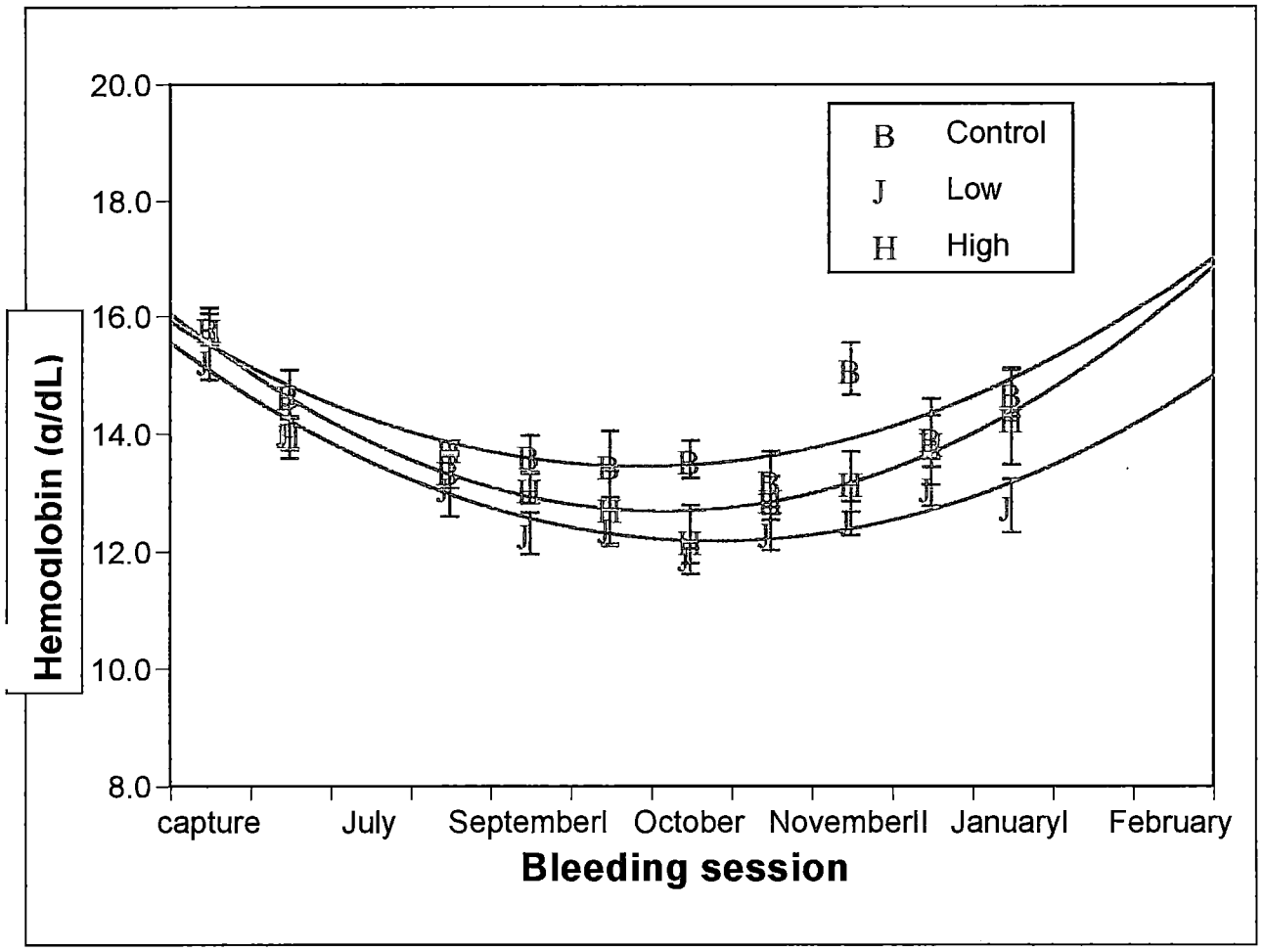


Fig. 3 – Levels of hemoglobin in blood of captive river otters exposed to 3 levels of hydrocarbons in their diet.

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

The wealth of data collected in this project will result in numerous additional publications than expected when the project was originally designed. Publication of these data is of extreme importance because results from this project can assist in interpretation of findings from field studies of other EVOS and non-EVOS funded projects. In this proposal funding is requested for completion of analyses and report writing for the project.

## PROPOSED PRINCIPAL INVESTIGATORS

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## PRINCIPAL INVESTIGATORS

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

Dr. R. Terry Bowyer, Professor of Wildlife Ecology, University of Alaska Fairbanks. Dr. Bowyer has an extensive publication record (70). He has conducted extensive research on river otters and impacts of *EVOS* on this species (10 publications). His responsibilities will include data analysis and assistance in report writing.

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

## OTHER KEY PERSONNEL

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Dr. Alan Rebar is Dean of the School of Veterinary Medicine and Professor of Veterinary Clinical Pathology at Purdue University. He is internationally recognized as an expert in the field of clinical pathology and toxicology. He has been involved in EVOS studies of sea and river otters since 1991. His responsibilities will include conducting the physiological, pathological and immunological investigations.

Dr. Paul W. Snyder
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Dr. Paul W. Snyder is an Assistant Professor of Pathology and Immunotoxicology and Director of the Clinical Immunology laboratory of the Department of Veterinary Pathobiology, Purdue University. He is also a Diplomate of the American College of Veterinary Pathologists. His research interests are in the area of mechanism based studies on the pathology and immunology of xenobiotics on biological systems. He has an NIH-funded project related to the immunobiology of environmental contaminants. His responsibilities will include conducting the physiological, pathological and immunological investigations.

Mr. Howard Golden
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Mr. Howard Golden is a researcher with the Alaska Dept. of Fish and Game, Division of Wildlife Conservation. His specialty is studying furbearers including river otters. He has extensive experience in live-trapping river otters as well as other furbearers. He will be involved in the trapping, transporting and release of the river otters.

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**2000 EXXON VALDEZ TRU! COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | $71.7 | $36.5 |
| Travel | $10.7 | $3.1 |
| Contractual | $68.1 | $11.8 |
| Commodities | $10.8 | $1.5 |
| Equipment | $0.0 | $0.0 |
| Subtotal | $161.3 | $52.9 |
| Indirect 25% | $32.5 | $13.2 |
| Project Total | $193.8 | $66.1 |
| Full-time Equivalents (FTE) | | 0.8 |
| Other Resources | $27.0 | $24.1 |

| LONG RANGE FUNDING REQUIREMENTS | |
|---|---|
| Estimated FY 2001 | Estimated FY 2002 |
| $0.0 | $0.0 |

Dollar amounts are shown in thousands of dollars.

Comments:

1. Indirect costs at 25% TDC (less equipment that resides with UA and subawards $25,000-250,000 @ 5%), as agreed with the University of Alaska Fairbanks.
2. Additional funding for radio-tracking is sought from other agencies. These funds will cover community involvement .
3. 6% of direct cost will be spent on attending workshops and professional meetings.

**FY00**

Prepared: 3-29-99

Project Number: 00348
Project Title: Responses of river otters to oil contamination
Name: Ben-David, IAB-UAF

FORM 4A
Non-Trustee
SUMMARY

**2000 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 2000 |
| M. Ben-David | Principal Investigator - Data analyses and report writing | | 6.0 | 4.6 | | 27.6 |
| O. A. Ormseth | Research Technician - Report writing (1 mo) | | 1.0 | 2.3 | | 2.3 |
| S. Trillhose | Research Technician - Stable isotope lab analyses | | 3.0 | 2.2 | | 6.6 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 10.0 | 9.1 | 0.0 | |
| | | | | | Personnel Total | $36.5 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| Description | | Price | Trips | Days | Per Diem | FY 2000 |
| M. Ben-David-Fairbanks to Anchorage - restoration workshop | | 0.3 | 1 | 4 | 0.1 | 0.7 |
| M. Ben-Daivd-Fairbanks to lower 48 - professional meetings | | 0.8 | 2 | 8 | 0.1 | 2.4 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | Travel Total | $3.1 |

**FY00**

Prepared: 3-29-99

Project Number: 00348
Project Title: Responses of river otters to oil contamination
Name: Ben-David, IAB - UAF

FORM 4B
Personnel
& Travel
DETAIL

**2000 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Stable isotope analyses - Water Research Center, UAF, 150 samples est. @ $15.0 per sample | 2.3 |
| Hydrocarbon analyses - Auke Bay Laboratory, 2 samples est. @ $600.0 per sample | 1.2 |
| PCB analyses - CT&E Laboratories Anchorage 15 samples est. @ $105.0 per sample | 1.6 |
| Testosterone analyses, IAB, UAF 165 samples est. @ $10.0 per sample | 1.7 |
| Publication costs 4 manuscripts @ $1,000 per one | 4.0 |
| Duplication, computer, and phone charges | 1.0 |
| **Contractual Total** | $11.8 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Computer software (statistical and graphics) | 1.5 |
| **Commodities Total** | $1.5 |

**FY00**

Prepared: 3-29-99

Project Number: 00348
Project Title: Responses of river otters to oil contamination
Name: Ben-David, IAB - UAF

FORM 4B
Contractual & Commodities DETAIL

| New Equipment Purchases: | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | 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 |
| 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 | |
| Masspectrometer (Water Research Center - UAF) | 2 | |
| Computer | 1 | |

**FY00**

Project Number: 00348
Project Title: Responses of river otters to oil contamination
Name: Ben-David, IAB - UAF

FORM 4B
Equipment
DETAIL

Prepared: 3-29-99

# The *Exxon Valdez* Oil Spill: Guidance for Future Research Activities "Submitted Under the BAA #52ABNF900033"

| | |
|---|---|
| Project Number: | 00360 - BAA |
| Restoration Category: | |
| Proposer: | Chris Elfring, Polar Research Board, National Research Council |
| Lead Trustee Agency: | |
| Cooperating Agencies: | |
| Alaska SeaLife Center: | No |
| Duration: | 1st year, 2-year project (24-month total) |
| Cost FY 00: | $351,151 |
| Cost FY 01: | $122,859 |
| Geographic Area: | |
| Injured Resource/Service: | potentially all |



## ABSTRACT

The National Research Council's Polar Research Board (PRB) and Board on Environmental Science and Toxicology propose to appoint a special committee to review the scope, content, and structure of the draft science plan the *Exxon Valdez* Oil Spill Trustee Council is preparing to guide long-term research and monitoring in the northern Gulf of Alaska. To provide context for reviewing the draft plan, the committee formed to accomplish this task will become familiar with the overall program of damage assessment and restoration research and monitoring activities that has been sponsored by the Trustee Council. The committee will prepare a final report with conclusions and recommendations intended to give guidance on the nature and scope of future research and monitoring activities in the northern Gulf of Alaska.

## INTRODUCTION

The Polar Research Board (PRB) and Board on Environmental Science and Toxicology, units of the National Research Council (NRC), propose to review the scope, content, and structure of the draft science plan the *Exxon Valdez* Oil Spill Trustee Council is preparing to guide long-term research and monitoring in the northern Gulf of Alaska. To provide context for reviewing the draft plan, the committee formed to accomplish this task will become familiar with the overall program of damage assessment and restoration research and monitoring activities that have been sponsored by the Trustee Council. The committee will prepare a final report with findings and recommendations intended to give guidance on the nature and scope of future research and monitoring activities in the northern Gulf of Alaska.

This study will be conducted by a special committee of volunteer experts, supported by a small staff and following standard NRC procedures regarding committee selection, committee operation, and report review. The committee will be composed of approximately 12 participants selected to have appropriate expertise and experience for the task. The committee will meet five times over a period of 20 months to gather information, deliberate, and produce a final report with conclusions and recommendations. This proposal seeks support for this activity in the amount of $474,010.

The NRC is the operating arm of the National Academy of Sciences and the National Academy of Engineering. It is a private, nonprofit organization operating under the authority of a charter granted by the Congress in 1863. The NRC is charged to be an independent advisor to the federal government and the nation on scientific and technical issues. This study will be managed by the Polar Research Board (PRB) with assistance from the Board on Environmental Studies and Toxicology (BEST). The mission of the PRB is to promote excellence in polar science and understanding of issues in cold regions by conducting studies and other activities in the natural and social sciences, technology, environment, and natural resources management. The mission of BEST is to conduct studies of environmental pollution problems affecting human health, human impacts on the environment, and the assessment and management of related risks to human health and the environment.

## NEED FOR THE PROJECT

### A. Statement of the Problem

In 1989, the *T/V Exxon Valdez* spilled 11 million gallons of crude oil into Prince William Sound in Alaska. In 1991, the U.S. District Court approved a civil settlement that required Exxon Corporation to pay the United States and the State of Alaska $900 million over 10 years to restore the resources injured by the spill and compensate for the reduced or lost services (human uses) the resources provide. Under the court-approved terms of

the settlement, a Trustee Council of three federal and three state members was formed to administer the funds. The mission of the Council is to return the environment to a "healthy, productive, world-renowned ecosystem" by restoring, replacing, enhancing, or acquiring the equivalent of natural resources injured by the spill and the services provided by those resources.

Funds from the *Exxon Valdez* Oil Spill Trustee Council (EVOS) have been disbursed for almost 10 years, at first for damage assessment activities (approximately 1989-1991) and then in relation to identified important "resource clusters," or communities/resources affected by the oil spill (1992 to present). These include: (1) pink salmon; (2) Pacific herring; (3) Prince William Sound ecosystem assessment; (4) sockeye salmon; (5) cutthroat trout, Dolly Varden trout, rockfish, and pollock; (6) marine mammals; (7) nearshore ecosystem communities; (8) seabird/forage fish and related resources; (9) archaeological resources; (10) subsistence resources; (11) reduction of marine pollution; (12) habitat improvement; and (13) ecosystem synthesis. Extensive research has been conducted in each of these areas over the decade, both under the auspices of the Trustee Council and the Exxon Corporation and by others, making this the most studied cold water marine oil spill in history.

The final payment from the Exxon Corporation will arrive in 2002, after which activities will be funded solely out of the Restoration Reserve, which was created from portions of the Exxon Corporation payments saved over the previous 10 years. A plan to guide future science activities is being developed. The purpose of this study would be to provide an independent scientific review of the draft plan for long-term monitoring and research to help ensure that plan is complete and scientifically sound. The study will review the plan's scope, content, and structure.

To plan for future science activities requires some understanding of the activities conducted to date. Thus, as context for reviewing the draft science plan, the committee will spend some time becoming familiar with the overall program of damage assessment and restoration research and monitoring activities that have been sponsored by the Trustee Council.

**B. Rationale/Link to Restoration**

An independent assessment of the proposed science plan is important to help the Trustee Council plan for the wise and sustainable use of funds contained in the Restoration Reserve and to ensure that decision-makers plan the best possible strategy for continued, long-term research and monitoring.

### C. Location

This project is a review of the scope, content, and structure of the draft science plan the *Exxon Valdez* Oil Spill Trustee Council is preparing to guide long-term research and monitoring in the northern Gulf of Alaska, and thus deals with many locales.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The committee charged to conduct this study will establish contact with the relevant communities so they are aware of our activity, most likely through the Public Advisory Group or the community liaisons. The study itself will have no direct impacts on the communities. When the final report is available, a summary will be made widely available, copies will be available through the National Academy Press, and the report will be posted in full on the National Academy of Sciences website.

## PROJECT DESIGN

### A. Objectives

This study will provide an independent scientific review of the Trustee Council's draft plan for a long-term, interdisciplinary research and monitoring program in the northern Gulf of Alaska.

Specifically, the committee appointed to conduct this study will:

- Gain, through briefings and literature review, an overview of the damage assessment, research, and monitoring activities conducted to date under the auspices of Trustee Council funding, including basic familiarity with work in each of the resource clusters.
- Review in detail the scope, content, and structure of the *Exxon Valdez* Oil Spill Trustee Council's draft plan for long-term research and monitoring.
- Produce a final report with conclusions and recommendations to guide the Trustee Council and the public in decision-making about the design and implementation of a long-term research and monitoring strategy for the northern Gulf of Alaska.

The retrospective elements of the study will be of an overview nature, with the goal of identifying lessons that can be learned to ensure that the future science program is well planned. The committee will not examine land acquisition or habitat protection efforts, except where related to the science program or in general as needed to understand the full scope of the Council's activities.

## B. Methods

This study will be conducted by a multidisciplinary committee of approximately 12 members that includes experts in a variety of relevant fields such as northern latitudes ecology, biological oceanography, fisheries biology, intertidal and subtidal communities, marine mammal biology, ornithology, population dynamics, environmental assessment, cold water oil spill chemistry and impacts, environmental restoration, and long-term research and monitoring. Committee members serve as volunteers, receiving reimbursement for travel and direct expenses only. They will be selected by the Academy to bring disciplinary expertise and a diversity of experience and perspectives; no members will have ties to parties involved in related litigation. Nominations for committee members will be sought from the involved boards, the National Academy of Sciences and the National Academy of Engineering, the Trustee Council, the research community, and relevant agencies and nongovernmental organizations. All members will be subject to standard NRC procedures regarding bias and conflict of interest.

The committee will meet 5 times over a 20 month period, first to become familiar with the existing science program and then to review the draft research and monitoring plan. The committee may seek assistance from experts not on the committee to help understand past activities or context. Close coordination with the Trustee Council staff will be necessary so the committee's review is timed to meet the Council's needs and for assistance in locating materials and information.

From its information-gathering activities and deliberations, the committee will develop a final report with conclusions and recommendations about the draft plan for future long-term monitoring and research in the Gulf of Alaska. The report development process will conform fully with the review procedures of the NRC.

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

Not applicable.

# SCHEDULE

## A. Measurable Project Tasks

FY 2000 (October 1, 1999 - September 30, 2000)

| | |
|---|---|
| Oct/Nov: | Committee nomination process begins<br>Committee selection completed; background materials compiled |
| January: | First meeting: orientation and information-gathering activities (in conjunction with Restoration Workshop) |
| Mar/April: | Second meeting: information-gathering activities and analysis of draft science plan |

| | |
|---|---|
| June/July: | Third meeting: continued discussions, assignments, and report preparation |
| Aug/Sept: | Fourth meeting: deliberations of conclusions and recommendations |

FY 2001 (October 1, 2000 – May 31, 2001)

| | |
|---|---|
| Oct/Nov: | Fifth meeting: final report writing workshop |
| November: | Report submitted for outside review |
| December: | Response to review |
| Dec/Jan: | Final revisions; Academy approvals |
| January: | Report delivery (prepublication copies) |
| Spring: | Published volume available; dissemination |

### B. Project Milestones and Endpoints

In the first two meetings, the committee will gain an overview of the research and monitoring activities conducted to date and become familiar with the content of the draft science plan. By the third meeting, the committee should be familiar enough with the program to begin substantive deliberations. As the committee proceeds, it will focus on report writing and development of conclusions and recommendations regarding the scope, content, and structure of the *Exxon Valdez* Oil Spill Trustee Council's draft plan for long-term research and monitoring. This will include whether the plan adequately addresses gaps in the knowledge base and existing uncertainties, as well as broader issues related to the plan's overall effectiveness for guiding continued efforts to return the Gulf of Alaska to a "healthy, productive, and world-renowned ecosystem."

The NRC committee will provide quarterly reports on the project's progress and process. The committee will attend the year 2000 annual restoration workshop as orientation to its tasks; representatives will attend the year 2001 workshop to deliver the committee's results, pending all Academy review procedures and approvals. According to standard NRC procedures, the committee will not provide drafts for review by EVOS but will follow standard NRC review procedures.

### C. Completion Date

The committee's report will be delivered to the Trustee Council and released to the public in January 2001. This product will be in final, albeit prepublication, form with a published volume to follow from the National Academy Press within approximately three months. The delivery of the final published report will be in lieu of the required April 15, 2001 annual report.

## PUBLICATIONS AND REPORTS

According to standard Academy operating procedures, no drafts or portions of the report will be conveyed; the final report will be submitted after it has completed the full

Academy review process, expected by January 2001. The committee will provide periodic progress reports, noting the committee's activities and process. Reports resulting from this effort shall be prepared in sufficient quantity to ensure their distribution to the sponsor and to other relevant parties in accordance with Academy policy. Reports will be made available to the public without restrictions.

## PROFESSIONAL CONFERENCES

This proposal contains a request for travel funds for the full committee to attend the January 2000 Restoration Workshop and at the same time hold their own first orientation meeting. The proposal also includes funds for the chair of the committee and one staff to attend the 2001 meeting of EVOS researchers.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will help the Trustee Council in its efforts to synthesize and integrate the extensive research efforts conducted so far, and apply those lessons to the draft science plan. The committee will likely be briefed by Trustee Council staff and sample principal investigators, visit field sites, and take other actions to gain a solid overview of the program and determine whether the scope and nature of the draft science plan is appropriate.

## PROPOSED PRINCIPAL INVESTIGATOR

This study will be conducted by a volunteer committee composed of carefully selected scientists with expertise in northern latitudes ecology, biological oceanography, fisheries biology, intertidal and subtidal communities, marine mammal biology, ornithology, population dynamics, environmental assessment, cold water oil spill chemistry and impacts, environmental restoration, and long-term research and monitoring. The committee will be selected via standard NRC procedures, including wide polling of the scientific community, to identify candidates. Final selection of members remains the responsibility of the Executive Office of the National Research Council.

The staff officer who is expected to be responsible for the activity will be:

Chris Elfring, Director
Polar Research Board (HA 454)
National Research Council
National Academy of Sciences, National Academy of Engineering
2101 Constitution Avenue NW
Washington, DC 20418
202-334-3426
202-334-1477
celfring@nas.edu

Additional staffing will be provided by:

David Policansky, Associate Director
Board on Environmental Science & Toxicology

National Research Council
National Academy of Sciences, National Academy of Engineering
2101 Constitution Avenue NW
Washington, DC 20418

## PRINCIPAL INVESTIGATOR

The substantive work of this activity will be performed by the committee appointed for the task. Project management is expected to be from CHRIS ELFRING, Director of the National Research Council's Polar Research Board (PRB). She joined the NRC/NAS in 1988, serving first as a senior study director for the Water Science and Technology Board, where she directed studies such as *New Strategies for America's Watersheds* (1998), *Flood Risk Management and the American River Basin* (1995), and *Water Transfers in the West: Efficiency, Equity, and the Environment* (1992). Other projects have focused on soil and water research priorities for developing countries, climate change and water management, the environmental impacts of irrigation, and science in the national parks. Since joining the PRB in 1995, Ms. Elfring has been involved in a variety of studies, including: *Future Directions for NSF's Arctic Natural Sciences Program* (1998), *NOAA's Arctic Research Initiative: Proceedings* (1997), *The United States In Antarctica: Comments from the PRB* (1997), *The Arctic Aeromedical Laboratory's Thyroid Function Study: A Radiological Risk and Ethical Analysis* (1996), and *The Bering Sea Ecosystem* (1996). Before coming to the NRC, Ms. Elfring was a policy analyst at Congress's Office of Technology Assessment, where she focused on natural resource management.

Any restriction relating to changing the "principle investigator" is not applicable because the key individuals responsible for the study are not NRC employees. A change in the responsible staff officer assigned to the project will have no impact on the award or completion of the assigned tasks. In the evaluation of any proposal, the determination for award is not based on the expertise of this individual but on the reputation of the Academy and its system of expert committees. The NRC will advise in advance of any change in staff, but cannot be assured of objectivity if the sponsoring agency has the right to approve or disapprove the staff assigned to the project.

## OTHER PERSONNEL

The committee's membership will be determined upon assurance that the project will proceed, following normal NRC procedures and with selection of the committee the responsibility of the NRC. Oversight for the study will be provided by the Polar Research Board. Its membership includes:

Donal Manahan, University of Southern California (chair)
Richard Alley, Pennsylvania State University
Anthony Gow, CRREL, New Hampshire
Bernard Hallet, University of Washington

David Hofmann, NOAA, Boulder, CO
James Morison, University of Washington
Carole Seyfrit, Old Dominion University
Thomas Taylor, University of Kansas
(4 new members to be appointed in 4/99)

## OTHER RELEVANT INFORMATION

FEDERAL ADVISORY COMMITTEE ACT (FACA)

The Academy has developed interim policies and procedures to implement Section 15 of the Federal Advisory Committee Act, 5 U.S.C. App. § 15. Section 15 includes certain requirements regarding public access and conflicts of interest that are applicable to agreements under which the Academy, using a committee, provides advice or recommendations to a Federal agency. In accordance with Section 15 of FACA, the Academy shall submit to the government sponsor(s) following delivery of each applicable report a certification that the policies and procedures of the Academy that implement Section 15 of FACA have been substantially complied with in the performance of the contract/grant/cooperative agreement with respect to the applicable report.

Public Information About the Project:

In order to afford the public greater knowledge of Academy activities and an opportunity to provide comments on those activities, the Academy may post on its website (http://www.nas.edu) the following information as appropriate under its procedures: (1) notices of meetings open to the public; (2) brief descriptions of projects; (3) committee appointments, if any (including biographies of committee members); (4) report information; and (5) any other pertinent information.

The NRC will maintain a public access file containing copies of materials and data made available to the committee, so these are available to the public. Limited, selected materials such as drafts of their report and personal financial disclosure forms are not made public.

**2000 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET**

October 1, 1999- September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $82,077.0 |
| Travel | | $138,630.0 |
| Contractual | | $17,895.0 |
| Commodities | | $600.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $239,202.0 |
| Indirect | | $111,949.0 |
| Project Total | $0.0 | $351,151.0 |
| Full-time Equivalents (FTE) | | 0.9 |

LONG RANGE FUNDING REQUIREMENTS

| | | Estimated FY 2001 | Estimated FY 2002 | | |
|---|---|---|---|---|---|
| | | $122,859.0 | | | |

Dollar amounts are shown in thousands of dollars.

Other Resources

Comments:
Under contractural please note that we have included copying, technology, postage, phone charges, and meeting expenses. These are NOT necessarily contracted out.
Office supplies have been included under commodities.

**FY00**

Prepared:

Project Number: 00360 -BAA
Project Title: Exxon Valdez Oil Spill Study
Name: National Academy of Sciences/Polar Research Board

FORM 4A
Non-Trustee
SUMMARY

**2000 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET**

October 1, 1999- September 30, 2000

| Personnel Costs: | | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|---|
| | Name | Position Description | | Budgeted | Costs | Overtime | FY 2000 |
| | Chris Elfring | Director, PRB | | 12.0 | 3022.9 | | 36,274.8 |
| | David Policansky | Sr. Staff Officer, BEST | | 12.0 | 1300.0 | | 15,600.0 |
| | Robert Greenway | Project Assistant | | 12.0 | 767.0 | | 9,204.0 |
| | Toni Greenleaf | Administrative Associate | | 12.0 | 123.3 | | 1,479.6 |
| | | Fringe Benefits for above @27.11% | | | | | 16,959.0 |
| | TBD | Summer Intern | | 2.0 | 1280.0 | | 2,560.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | Subtotal | | 50.0 | 6493.2 | 0.0 | |
| | | | | | | **Personnel Total** | $82,077.4 |

| Travel Costs: | | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|---|
| | Description | | Price | Trips | Days | Per Diem | FY 2000 |
| | Anchorage | Workshop in Winter 2000+Committee Meeting | 1500.0 | 15 | 90 | 145.0 | 35,550.0 |
| | Anchorage | (or other Alaska City ) (2 separate committee meetings) | 1500.0 | 30 | 120 | 224.0 | 71,880.0 |
| | Anchorage | (or other Alaska City TBD) (1committee meeting) | 1500.0 | 15 | 60 | 145.0 | 31,200.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | (These estimates are based on current airfares, | | | | | 0.0 |
| | | assuming reasonable restrictions on the travelers.) | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | **Travel Total** | $138,630.0 |

**FY00**

Prepared:

Project Number:
Project Title: Exxon Valdez Oil Spill Study
Name: National Academy of Sciences/Polar Research Board

FORM 4B
Personnel
& Travel
DETAIL

**2000 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET**

October 1, 1999- September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Photocopies | 1,757.0 |
| Postage/Delivery | 1,200.0 |
| Technology/Communications | 6,138.0 |
| Meeting Expenses (room rental, breaks, transportation, site visits) | 8,500.0 |
| Publications/computer research/searches | 300.0 |
| **Contractual Total** | $17,895.0 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Office Supplies | 600.0 |
| **Commodities Total** | $600.0 |

**FY00**

Prepared:

Project Number:
Project Title: Exxon Valdez Oil Spill Study
Name: National Academy of Sciences/Polar Research Board

FORM 4B
Contractual & Commodities DETAIL

**2000 EXXON VALDEZ TRU COUNCIL PROJECT BUDGET**

October 1, 1999- September 30, 2000

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 2000 |
| None | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

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

**FY00**

Project Number:
Project Title: Exxon Valdez Oil Spill Study
Name: National Academy of Sciences/Polar Research Board

FORM 4B
Equipment
DETAIL

Prepared:

*EXXON VALDEZ* Oil Spill Trustee Council

**FY 00 Detailed Project Description**

# Improved salmon escapement enumeration using remote video and time-lapse recording technology

| | |
|---|---|
| **Project Number:** | 00366 |
| **Restoration Category:** | Monitoring |
| **Proposer:** | ADF&G |
| **Lead Trustee Agency:** | ADF&G |
| **Cooperating Agencies:** | |
| **Alaska SeaLife Center:** | No |
| **Duration:** | 2nd year, 3-year project |
| **Cost FY 1999:** | $ 53,473 |
| **Cost FY 2000:** | $ 49.5 K |
| **Cost FY 2001:** | $ 13.3 K |
| **Cost FY 2002:** | $ |
| **Geographic Area**: | Lower Cook Inlet |
| **Injured Resource/Service**: | salmon/commercial fishing |


## ABSTRACT

Salmon resources and services within the spill area, and particularly within Prince William Sound, were injured by the 1989 *Exxon Valdez* oil spill and have not yet fully recovered. To monitor the recovery of salmon stocks in the spill area and improve escapement information used to set spawning escapement goals, we propose to develop remote video and time-lapse recording technology for enumerating salmon escapement. Remote video has the potential to provide accurate, archivable documentation of salmon escapements well beyond the capacity of aerial survey indices, and well below the cost of weir and sonar projects. Videotapes can be retrieved and reviewed weekly to facilitate in-season management of commercial fisheries.

## INTRODUCTION

Aerial survey has been used to monitor salmon escapement in clear streams throughout Alaska for over 35 years (Bevan 1961). This technique is favored for remote and marginally productive drainages which otherwise may go unassessed due to the high cost of intensive monitoring methods (e.g., weir, sonar) relative to the stream's modest escapement. However, aerial survey has several drawbacks. Observer experience, water clarity, stream morphology and habitat type, timing of survey flights, and stream residency are just a few factors shown to influence the accuracy and precision of aerial survey estimates of salmon escapement (see Bevan 1961, Evzerov 1981, Neilson and Geen 1981, Cousens et al. 1982, Shardlow et al. 1987, Perrin and Irvine 1990, Hill 1997, and Bue et al. 1998a). At best, aerial survey provides consistent indices of in-river escapement among years. It does not provide accurate, reliable estimates of spawner-abundance, particularly when in-river exploitation of salmon is high and observer efficiency and stream residency are not precisely known (Perrin and Irvine 1990, Bue et al. 1998a).

Accurate, reliable estimates of spawner abundance are required to monitor the recovery of damaged salmon resources, set appropriate spawning escapement goals for individual streams, and manage commercial fisheries in season. Because aerial survey cannot always provide this level of information and more accurate methods are prohibitively expensive for streams with marginal escapements, a niche exists that remote video technology may be able to fill. Fishery biologists have long considered the potential for photographic enumeration to eliminate the biases inherent to human derived aerial and tower counts of salmon escapement. In the late 1940's and early 1950's, researcher's experimented with aerial and tower based photography to count sockeye salmon in the Bristol Bay area (see Kelez 1947, Eicher 1953, and Mathisen 1962). While these early experiments showed promise, their feasibility was reduced by the state of technology of cameras and recording equipment from this era.

Many technological advancements have occurred since that time and recent video and time-lapse recording systems have proven effective for capturing remote images of adult (Hatch et. al 1994) and juvenile salmonids in controlled field situations (Irvine et. al 1991). In Chignik, Alaska, researchers are using underwater video equipment to facilitate enumeration of adult salmon passing a deep-water weir (Dave Owens, ADF&G Kodiak, personal communication). The Chignik system is powered by a gas generator and maintained by a field crew. In the Pacific Northwest, researchers are experimenting with stand-alone underwater video systems associated with partial weirs (P. Mundy, P. Mundy and Assoc., personal communication). An unmanned underwater system is not practical for most Alaskan streams because the camera would be vulnerable to inquisitive bears and other mammals. In FY99 we propose to develop an unmanned

video system that can be deployed above small streams, out of the reach of bears. The video system will document sockeye, pink, and coho salmon escapement into Delight Lake. Time-lapse images will be recorded onto a VCR powered by 12-volt batteries. Solar and hydropower generators will maintain the batteries. A weir will be operated concurrently to determine the accuracy of video counts. In FY00 we will evaluate the camera's performance counting pink and chum salmon escapement in a short, intertidal stream.

## NEED FOR THE PROJECT

### A. Statement of Problem

Salmon resources and services were injured by the 1989 *Exxon Valdez* oil spill. Accurate, reliable estimates of spawner abundance are required to monitor the recovery of damaged salmon resources, set appropriate spawning escapement goals for individual streams, and manage commercial fisheries in season. Aerial survey estimates of spawning escapement are often biased by conditions (e.g., observer experience/efficiency, timing of flights, etc.) that are difficult to account for, leading to imprecise indices of spawning escapement. Because accurate escapement monitoring is so important for salmon management and documenting the recovery of salmon resources and services, reliable, cost-effective techniques should be developed to improve escapement estimation where aerial survey is currently used.

### B. Rationale/Link to Restoration

Salmon resources throughout the spill area, and particularly in Prince William Sound (Bue et al. 1996, Bue et al. 1998b) 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 salmon stocks within the spill area and statewide. Improved escapement 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 and commercial fishing services.

### C. Location

Development of this improved escapement monitoring technology will occur in Lower Cook Inlet (Southern Kenai Peninsula). However, project benefits could be realized throughout the spill area

and anywhere in Alaska where aerial survey is currently being used to monitor salmon escapement in small, clear streams.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Although McCarty Fiord and much of the Kenai Peninsula's outer coast is contained within Kenai Fiords National Park (KFNP), Delight Lake and its outlet stream (Delight Creek) are owned by the Port Graham Corporation (PGC). Port Graham residents have a long history of using these salmon resources for commercial and subsistence purposes and are concerned for the area's continuing productivity. Although the remote video system could be evaluated elsewhere, a unique opportunity exists at Delight Lake to fulfill PGC and KFNP requests to provide improved monitoring of salmon escapement and production.

## PROJECT DESIGN

### A. Objectives

1. (FY99): Determine the accuracy and reliability of a remote video system for estimating sockeye salmon escapement in small streams, and
2. (FY00): Determine the accuracy and reliability of a remote video system for estimating pink and chum salmon escapement in tidally influenced streams where intertidal spawning occurs.

### B. Methods

The straightforward nature of this monitoring project precludes the need to test hypotheses. A remote video camera positioned above the stream channel will capture images onto a time-lapse video cassette recorder (VCR). For multi-species returns, a second camera will be deployed underwater to apportion the species composition of the total return estimated by the overhead camera. A conventional picket weir will be operated concurrently with the camera(s) so the accuracy of video escapement estimates can be determined. The reliability (i.e., field durability) of the video system will be judged by the percentage of time that it is inoperable or unable to effectively count fish.

We selected Delight Lake outlet to test the video system in FY99 for several reasons: 1) a low-gradient, clear-water stream exists, on which a weir and video system can readily be operated; 2) the lake is typical of lake spawning sockeye systems where fish are only visible to aerial surveyors while they're ascending the outlet stream; because fish often disappear when they enter the lake, area-under-the-curve estimates of spawning escapement are problematic; and 3) evaluating the video system on Delight lake provides an opportunity to supplement adult escapement data collected under EVOS Project No. 97254 (Edmundson et al. 1998).

**Video**

Siting of the camera will be critical to its performance. The preferred stream section will be relatively shallow (<1.5 m), narrow (<20 m) and free of excessive surface turbulence. Pools and slow runs will be avoided as fish may have a tendency to mill about and be counted multiple times. If an overhanging tree is not available to position the camera above the chosen site, a support tower will be erected. The tower will consist of a shortened metal light pole, identical to those observed along many roadways. The 5-7 meter vertical pole will be securely attached to the bank and the horizontal mast arm will extend out over the stream where the downward looking camera will be attached.

A light-green "flash panel" (1.27-cm mesh beach seine) will be fixed to the streambed to enhance the contrast of fish swimming below the camera. In other applications flash panels have proven effective without spooking or entangling fish. A polarizing filter will be attached to the camera to reduce water surface glare; if necessary, v-shaped float logs will be placed upstream of the video site to eliminate surface turbulence. The camera will feed a continuous video signal to a time-lapse VCR that will record one image every 1.0 seconds. This interval will allow a single 160-minute VHS tape to last eight days (assuming 20 hours of recording time/day). The camera's field of view will be sufficiently wide to assure that no fish bypass the video site without being documented on film, facilitating near-census-quality escapement data. The only fish not photographed will be those that pass during about 4.0 hours of darkness. Staff will periodically monitor the site at night to estimate the extent of nocturnal migration. If necessary, auxiliary lighting can be incorporated so the camera operates 24 hr/d. This will enable estimation of the total escapement for independent comparison with weir counts.

During periods when more than one species is returning, a second camera will be deployed underwater to estimate species composition. Data from this camera will be used to apportion the total return estimated by the overhead camera. The underwater camera will be protected inside a steel pipe securely attached to the stream bottom. A multiplexer will allow time-lapse images from both cameras to be recorded onto the same VCR. Use of a multiplexer during tape review

will enable reviewers to evaluate both sets of recorded images simultaneously on a split screen monitor.

The camera(s) and VCR will be powered by four 12-V deep-cycle batteries (105 amp-hour) and will be recharged by a small hydro-generator and possibly two 4.1 amp/hour solar panels. The VCR and batteries will be housed in a weather/bear proof strong box secured to the streambank above the annual high-water elevation. All necessary wiring will be housed in conduit so it will not be vulnerable to birds, bears or rodents. Approximately once a week, research staff will service the equipment, change cassette tapes in the machine, and return the recorded tape to Homer (ADF&G) for timely review.

It is possible that microwave technology could allow ADF&G to directly transmit video images to Homer in the near future. This would preclude the need to switch out videotapes, enabling considerable savings in air charter costs. A Homer based videographer recently succeeded in transmitting remote images from Gull Island (Kachemak Bay) to Homer, a distance of approximately 6 miles (Daniel Zatz, personal communication). Further experimentation in the coming months will determine the feasibility of using a repeater to facilitate transmissions up to 100 miles. Remote-video monitoring of salmon escapements, and direct transmission of the images to field offices for analysis and archival onto VHS tapes, would facilitate better quality data than aerial surveys currently provide, and at reduced costs. Developing image-recognition software that enables auto-enumeration would further reduce the labor and costs involved with remotely monitoring salmon escapements (Irvine et al. 1991, Hatch et al. 1998). The ADF&G will pursue these advancements once the present application proves feasible.

**Cross Validation**

A conventional picket weir will be operated concurrently with the video camera to provide a basis for determining the accuracy of video counts. Weirs are recognized as the most accurate escapement monitoring technique available (Cousens et al. 1982); in the absence of washouts during freshets, they provide a complete census of the run. The weir and associated field camp will be operated in the same location and manner as Project 97254 (Edmundson et al. 1998). Weir operation and video monitoring will begin prior to the start of the adult run and continue until the daily passage rate is <1% of the total escapement to date. Aerial surveys of spawning escapement will also be conducted concurrently with video enumeration to provide a basis for comparison between the three escapement monitoring techniques.

**Intertidal spawning (FY00)**

If remote video proves feasible for enumerating sockeye escapement, we will investigate its application for estimating pink and chum salmon escapement into tidally influenced streams. Pink and chum salmon often spawn in intertidal areas where weirs are difficult to operate. Aerial and foot surveys frequently are used to assess escapement in these situations (Bucher and Hammarstrom 1997). It may be feasible to deploy remote cameras in the intertidal section of a stream to document intertidal spawners and simultaneously count salmon escaping upstream. Because many individuals may enter and exit the stream with the tides, the daily escapement of upstream spawners would be tallied as the number of upstream migrants minus the number of downstream migrants. Separate estimates will be made for the number of intertidal spawners by factoring streamlife into an area-under-the-curve estimate of total observed spawners (Hill 1997, Bue et al. 1998a). Total spawning escapement will be estimated by adding the estimated escapements of the upstream and intertidal spawning components of the run. A weir can be operated above tidal influence to document the actual number of upstream spawners for independent comparison with video counts. Port Dick Creek will be an excellent place to pursue this application because it sustains runs of both pink and chum salmon. Pursuing the project on Port Dick Creek also provides an opportunity to continue monitoring the success of project 98139A2 (Dickson et al. 1999).

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

Not applicable

## SHEDULE

### A. Measurable Project Tasks for FY99

| | |
|---|---|
| October-January: | Purchase video equipment and associated materials. |
| January-April: | Fabricate strongbox for video equipment; arrange logistics for field camps and weir installation. |
| June: | Deploy camp, weir, and video equipment. |
| June-August: | Operate weir camp, maintain camera equipment, review tapes. |
| September: | Evaluate camera's performance against weir counts. |

### B. Measurable Project Tasks for FY00

| | |
|---|---|
| November: | Present first year results at AFS meeting in Kodiak. |
| January-April: | Present poster at Annual EVOS workshop; turn in EVOS Annual Report, DPD, and budget for FY01 activities. |
| Late June: | Deploy camp, weir, and video equipment. |
| July-August: | Operate weir camp, maintain camera equipment, review tapes. |
| September: | Evaluate camera's performance against weir counts |

### C. Project Milestones and Endpoints

| | | |
|---|---|---|
| September 1999 | Objective 1: | Determine video system's accuracy and reliability by comparing video counts against weir counts. |
| September 2000 | Objective 2: | Determine feasibility of using remote video to count pink and chum salmon escapement in tidally influenced streams. |
| September 2001 | Obj. 1-2: | Complete project final report. |

### D. Completion Date

All project objectives will have been met by the end of FY00 and the project will close out in FY01. If remote video proves to be a reliable and cost-effective method for improving upon aerial survey estimates of spawning escapement, ADF&G may use normal agency funding to replace aerial surveys with video, where suitable. The ADF&G may also pursue development of microwave technology to transmit digital images directly to field stations, and image-recognition software to facilitate auto-enumeration.

## 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 in Kodiak, November 9-11, 1999) and publish them in a peer-reviewed journal (e.g., Transactions of Fisheries Management).

## PROFESSIONAL CONFERENCES

Travel funds have been requested to attend the EVOS annual workshops in Anchorage. If analyses can be completed in time, FY99 results will be presented at the 1999 Annual Meeting of the Alaska Chapter of the American Fisheries Society, held in Kodiak during November 9-11, 1999.

## NORMAL AGENCY MANAGEMENT

Along with monitoring the recovery of injured resources, the proposed project will improve the department's ability to assess and manage salmon resources within the spill area and elsewhere in Alaska. The department has few resources with which to develop new technology; without the Trustee Council's financial support, this project will not be funded in the near future. A unique opportunity exists for the EVOS Trustee Council to add to their legacy by supporting ADF&G's development of a new salmon counting technique that is likely to improve salmon management throughout Alaska.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Does not apply.

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

Does not apply.

## PROPOSED PRINCIPAL INVESTIGATOR

Edward O. Otis
Alaska Department of Fish and Game
P.O. Box 1402 Homer, AK 99603
(907) 235-8191
(907) 235-2448
tedo@fishgame.state.ak.us

## PRINCIPAL INVESTIGATOR

**Edward O. Otis**, Asst. Area Research Biologist for Lower Cook Inlet, Alaska Department of Fish and Game, Commercial Fisheries Division (CF), 3298 Douglas Place, Homer, AK 99603. **Education**: Master of Science, Fisheries Science, University of Arizona, 1994. Bachelor's of Science, Environmental Science, University of New Hampshire, 1988. **Professional Experience:** April 1996-present: Asst. Area Research Biologist for Lower Cook Inlet, Alaska Department of Fish and Game, CFMD, Homer, AK. Supervised by William R. Bechtol. Responsible for assessment and forecasting of Kamishak Bay herring stock; directs salmon and herring catch/escapement-sampling programs; forecasts Lower Cook Inlet salmon returns. April 1994-March 1996: Fishery Biologist, Kenai Fishery Resources Office, U.S. Fish and Wildlife Service, Kenai, AK. Supervised by Gary Sonnevil. Project leader for Andreafsky River (Yukon) adult salmon enumeration project: constructed and deployed resistance board/floating weir to count adult salmon; project leader for Kenai River rainbow trout radio-telemetry project: surgically implanted radio transmitters and tracked fish using mobile receivers and remote data loggers. June 1991-March 1994: Graduate Research Asst., Univ. of Arizona, Dept. of Renewable Natural Resources, Tucson, AZ. Supervised by Dr. O. Eugene Maughan. Designed and implemented field studies to assess the composition, abundance, and distribution of fishes in streams tributary to the Colorado River in Grand Canyon. Designed and implemented field study to inventory aquatic habitat available to stream fishes in Grand Canyon. August 1987-June 1991 (intermittent): Field biologist/technician, Kenai Fishery Resources Office, U.S. Fish and Wildlife Service, Kenai, AK. Supervised by Gary Sonnevil. Project Leader or team member on various field projects including: assessing adult salmon returns using weirs (Uganik R, Kodiak); developing new approaches to aging dolly varden and lake trout otoliths; enumerating emergent salmon fry (Tustumena Lake); investigating steelhead distribution and angler effort (Cold Bay); investigating run-timing and migration rates of chinook salmon (Kuskokwim River); and inventorying salmon spawning habitat (Ayakulik R., Kodiak).

**Selected Publications:**


Weiss, S.J., **E.O. Otis**, and O.E. Maughan. 1998. Spawning ecology of flannelmouth sucker *Catostomus latipinnis* (Catostomidae) in two small tributaries of the lower Colorado River. Environmental Biology of Fishes.

Otis, E.O. and W.R. Bechtol. 1997. Forecast of the Kamishak herring stock in 1997. Alaska Dept. of Fish and Game, Regional Information Report No. 2A97-03.

Otis, E.O. 1997. Lower Cook Inlet pink salmon forecast for 1997. Alaska Department of Fish and Game Regional Information Report No. 2A97-09.

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 Proceedings of the International Stock Assessment Symposium, 1997 Lowell Wakefield Conference (*in press*).

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Otis, E.O., and M.S. Dickson. 1999. Abundance, age, sex, and size statistics for sockeye, chum, and pink salmon in Lower Cook Inlet, 1996. Alaska Department of Fish and Game Regional Information Report No. 2A99-09.

## OTHER KEY PERSONNEL

Project Manager: Mark Dickson, Fish and Wildlife Technician IV. Mr. Dickson has been employed as a fish culturist and fish and wildlife technician with the Alaska Department of Fish and Game for the past 20 seasons. He has considerable experience managing salmon escapement related field projects, including: the *EVOS* Trustee Council funded Delight and Desire Lakes project (97254) and currently, the Port Dick Creek Restoration project (97139A2).

## LITERATURE CITED

Bevan, Donald E. 1961. Variability in aerial counts of spawning salmon. Journal of the Fisheries Research Board of Canada 18(3):337-348.

Bucher, W.A., and L.F. Hammarstrom. 1997. 1996 Lower Cook Inlet annual finfish management report. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Anchorage.

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Bue, B.G., S.M. Fried, S. Sharr, D.G. Sharp, J. Wilcock, and H.J. Geiger. 1998a. Estimating salmon escapement using area-under-the-curve, aerial observer efficiency, and stream-life estimates: the Prince William Sound pink salmon example. North Pacific Anadromous Fisheries Commission Bulletin 1:240-250.

Bue, B. G., S. Sharr, and J.E. Seeb. 1998b. Evidence of damage to pink salmon populations inhabiting Prince William Sound, Alaska, two generations after the *Exxon Valdez* oil spill. Transactions of the American Fisheries Society 127:35-43.

Cousens, N.B.F., G.A. Thomas, D.G. Swann, and M.C. Healey. 1982. A review of salmon escapement techniques. Canadian Technical Report of Fisheries and Aquatic Sciences 1108:129 pp.

Dickson, M., W. Bucher, and G. Coble. 1999. Tributary restoration and development project: Port Dick Creek, Lower Cook Inlet, Alaska, Exxon Valdez oil spill restoration project 1998 annual report (Restoration Project 98139-A2), Alaska Department of Fish and Game, Homer, Alaska.

Edmundson, J., M. Dickson, and W. Bucher. 1998. Limnology and fishery investigations concerning sockeye salmon production in Delight and Desire lakes, EVOS Restoration

Project 97254 Final Report submitted by the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development.

Eicher, G.J. 1953. Aerial methods of assessing red salmon populations in western Alaska. Journal of Wildlife Management 17(4):521-527.

Evzerov, A.V. 1981. An evaluation of the errors occurring in salmon census by aerial survey. Canadian Translations of Fisheries and Aquatic Sciences 4714:1-5. Translated from Salmonidae of the Far East, 1975 CVI:82-84.

Hatch, Douglas R., M. Schwartzberg, and P.R. Mundy. 1994. Estimation of pacific salmon escapement with a time-lapse video recording technique. North American Journal of Fisheries Management 4:626-635.

Hatch, D.R., J.K. Fryer, M. Schwartzberg, D.R. Pederson, and A. Wand. 1998. A computerized editing system for video monitoring of fish passage. North American Journal of Fisheries Management 18: 694-699.

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Irvine, J.R., B.R. Ward, P.A. Teti, and N.B.F. Cousens. 1991. Evaluation of a method to count and measure live salmonids in the field with a video camera and computer. North American Journal of Fisheries Management 11:20-26.

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Mathisen, O.A. 1962. Photographic enumeration of red salmon escapement. Pages 349-372 in Koo, T.S.Y (ed.) Studies of Alaska Red Salmon. Univ. of Wash. Publ. In Fish. New Ser. 1: 449 pp.

Neilson, J.D. and G.H. Geen. 1981. Enumeration of spawning salmon from spawner residence time and aerial counts. Transactions of the American Fisheries Society 110:554-556.

Perrin, C.J. and J.R. Irvine. 1990. A review of survey life estimates as they apply to the area-under-the-curve method for estimating the spawning escapement of Pacific salmon. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1733. 49 pp.

Shardlow, T., R. Hilborn, and D. Lightly. 1987. Components analysis of instream escapement methods for Pacific salmon (Oncorhynchus spp.). Canadian Journal of Fisheries and Aquatic Sciences 44:1031-1037.

**2000 EXXON VALDEZ TF EE COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| | | |
| Personnel | $32,016.0 | $32.0 |
| Travel | $495.0 | $1.9 |
| Contractual | $4,327.5 | $6.7 |
| Commodities | $5,600.0 | $3.6 |
| Equipment | $4,480.0 | $0.0 |
| Subtotal | $46,918.5 | $44.2 |
| General Administration | $4,901.5 | $5.3 |
| Project Total | $51,820.0 | $49.5 |
| | | |
| Full-time Equivalents (FTE) | | 0.6 |
| | Dollar amounts are shown in thousands of dollars. | |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| | | Estimated FY 2001 | Estimated FY 2002 | | |
|---|---|---|---|---|---|
| | | 13.3 K | $0.0 | | |

Comments:

FY00 costs include deploying the video and weir on a new river system to evaluate a different application (i.e., different species, tidal influence, etc.). Thus, FY00 costs will be similar to those expended in FY99 except that new equipment purchaces will be reduced. The FY00 budget is higher than was anticipated in the FY99 budget forecast. Additional expenses are required for increased air charter rates and for travel by the PI and Project Manager to Kodiak to deliver a paper at the Annual Meeting of the Alaska Chapter of the American Fisheries Society (AFS). The AFS conference, whose theme this year is- "Today's Technology for Tommorrow's Resources" is an ideal venue to present a paper on improving salmon escapement monitoring in Alaska through the use of remote video and time-lapse recording technology.

FY01 costs are closeout expenses related to completion of final and publishable reports. One thousand dollars were added to the anticipated FY01 expenditures to cover page charges; this cost had not been considered when this project was proposed.

*The Principal Investigator's salary will be funded entirely by ADF&G.

**FY00**

Prepared: 4/99

Project Number: 00366
Project Title: Improved salmon escapement enumeration using remote video and time-lapse recording technology
Agency: ADF&G

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2000 EXXON VALDEZ TF :E COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 2000 |
| **Field Personnel** | | | | | | 0.0 |
| Maintain and operate adult weir and video equipment | | | | | | 0.0 |
| | | | | | | 0.0 |
| Carla Milburn | Fisheries Technician II | 9B | 1.5 | 3600.0 | 1408.0 | 6,808.0 |
| Josephine Ryan | Fisheries Technician II | 9B | 1.5 | 3600.0 | 1408.0 | 6,808.0 |
| | | | | | | 0.0 |
| **Project Supervision** | | | | | | 0.0 |
| System design and construction, project management, | | | | | | 0.0 |
| video screening and report writing. | | | | | | 0.0 |
| Ted Otis* | Fishery Biologist II | 16C | 0.0 | 0.0 | | 0.0 |
| Mark Dickson | Fisheries Technician IV | 13J | 4.0 | 4600.0 | | 18,400.0 |
| | | | | | | 0.0 |
| | Subtotal | | 7.0 | 11800.0 | 2816.0 | |
| | | | | | **Personnel Total** | $32.0 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 2000 |
| | | | | | 0.0 |
| Homer-Anchorage and return. Annual EVOS Restoration Workshop | 135.0 | 1 | | | 135.0 |
| Lodging- 1 person, 3 days | | | 3 | 75.0 | 225.0 |
| Food per diem- 1 person, 3 days | | | 3 | 45.0 | 135.0 |
| | | | | | 0.0 |
| Homer-Kodiak and return. Annual Meeting of the Alaska Chapter | 422.0 | 2 | | | 844.0 |
| of the American Fisheries Society | | | | | 0.0 |
| Lodging- 2 people, 3 days | | | 3 | 100.0 | 300.0 |
| Food per diem- 2 people, 3 days | | | 6 | 45.0 | 270.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $1.9 |

**FY00**

Prepared: 4/99

Project Number: 00366
Project Title: Improved salmon escapement enumeration using remote video and time-lapse recording technology
Agency: ADF&G

FORM 3B
Personnel
& Travel
DETAIL

2000 EXXON VALDEZ TI EE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

| Contractual Costs: | Proposed |
|---|---|
| Description | FY 2000 |
| Air charter to transport camp. Two round trips @ 1.5 hrs/trip @ $665/hr (Dehavilland otter) | 1,995.0 |
| Air charter to support camp (food and supplies) and service remote video equipment, 8 round trips @ 1.5 hrs/trip @ $275/ hour (Cessna 185) | 3,300.0 |
| Air charter standby 3 hrs. @ 137.50/hr. | 412.5 |
| Photo developing and graphic arts (poster for annual EVOS meeting and presentation at American Fisheries Society Meeting) | 1,000.0 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $6.7 |

| Commodities Costs: | Proposed |
|---|---|
| Description | FY 2000 |
| Food: 2 people @ $20/day @ 75 days (2x20x75) | 3,000.0 |
| Consumables: lumber, aditional fencing (weir materials) video tapes, etc. | 300.0 |
| 100 gals. Stove oil @ $1.25/gal | 125.0 |
| Misc. electrical suppies for video system | 200.0 |
| **Commodities Total** | $3.6 |

**FY00**

Prepared: 4/99

Project Number: 00366
Project Title: Improved salmon escapement enumeration using remote video and time-lapse recording technology
Agency: ADF&G

FORM 3B
Contractual & Commodities DETAIL

| New Equipment Purchases: Description | Number of Units | Unit Price | Proposed FY 2000 |
|---|---|---|---|
| No new equipment purchases anticipated in FY00 | | | 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 |
|---|---|---|
| 12x15' Weatherport portable shelter and platform | 1 | ADF&G |
| Portable electric generator | 1 | ADF&G |
| 75' adult salmon counting weir | 1 | ADF&G |
| High Frequency radio | 2 | ADF&G |
| Camp supplies (cooking, lighting, etc) | 1 | ADF&G |
| Rain gear, hip boots | 2 | ADF&G |
| Adult salmon sampling kit | 1 | ADF&G |
| Personal computers | 2 | ADF&G |
| Complete inventory of additional equipment on file with ADF&G in Homer | | |

**FY00**

Project Number: 00366
Project Title: Improved salmon escapement enumeration using remote video and time-lapse recording technology
Agency: ADF&G

FORM 3B
Equipment
DETAIL

Prepared: 4/99

# Effects of Harbor Seal Metabolism on Stable Isotope Ratio Tracers

| | |
|---|---|
| Project Number: | 00371 |
| Restoration Category: | Research |
| Proposer: | University of Alaska Fairbanks |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | yes |
| Duration: | 2nd year, 3-year project |
| Cost FY 00: | $104.9 ($98.0 UAF plus $6.9 ADF&G General Admin) |
| Cost FY 01: | $96.3 ($90.0 UAF plus $6.3 ADF&G General Administration) |
| Geographic Area: | Prince William Sound/Gulf of Alaska |
| Injured Resource/Service: | Harbor seals |



## ABSTRACT

A major concern with the use of stable isotope tracers in ecosystem studies is the fidelity with which isotope ratios are transferred up food chains. Use of specific habitats or prey cannot be assessed if geographic gradients in isotope ratios are laid on top of trophic effects and/or prey switching. To remove these problems we will seek specific conservative biomarkers such as essential amino acids or fatty acids that carry isotope ratios unmodified by metabolism. Amino acids labeled with $^{15}N$ and $^{13}C$ will be used to follow transamination and carbon relocation during metabolic processes in the seals at the Alaska SeaLife Center. Specific fatty acid isolation and determination of suitability as habitat biomarkers will follow in year 3 of the project.

## INTRODUCTION

Stable isotope ratios have become an essential tool in the study of living organisms and their physiology. The hazards of handling radioisotopes and severe protocol requirements when using live organisms have resulted in a steadily increasing shift to the use of stable isotopes as tracers for both human and animal subjects. Some usages, such as the detection of *Helicobacter pylori* infections in ulcer patients, are now routine and are bringing stable isotope analysis to many hospitals as a standard method. In contrast to the employment of natural abundance techniques in the marine environment, most physiology experiments employ compounds enriched with $^{13}C$ or $^{15}N$ to enhance detectability and to follow the transfers to different metabolites within the organism. Improved lower limits of detectability and smaller sample size requirements now allow the use of stable isotopes where only radioisotopes would have worked in the past.

This proposal describes continuing experiments underway at the Alaska SeaLife Center (ASLC) and at the University of Alaska Fairbanks (UAF) to provide calibration and more detailed information on stable isotope transfers and fractionation in marine mammals (and perhaps sea birds in the future). This will enable better interpretation of natural abundance isotope data acquired in Prince William Sound and the adjacent Gulf of Alaska. Coordination with the studies of Dr. M. Castellini who is conducting feeding experiments and dietary studies at ASLC will lead to a thorough integration of efforts and optimization of the use of animal subjects in all years of the study. Year 1 has consisted of the refinement of analytical techniques isolating amino acids and will test for the presence of essential amino acids in harbor seals at ASLC. Succeeding years will focus on the search for biomarkers useful in identification of specific habitat usage and as indicators of the assimilation of various species of forage fishes.

Over the past two decades, isotope ratio analysis has emerged as a powerful tool in ecosystem research, both on the process scale and as a validation technique for large-scale ecosystem models (Michener and Schell, 1994). In relevant applications to this study, Saupe et al. (1989) and Schell et al. (1989) described a geographic gradient in isotope ratios in biota across the Alaskan Beaufort Sea and the Bering–Chukchi seas and showed that this gradient could be applied to describing bowhead whale natural history. The isotopic gradient arises from the primary producers in the ecosystem and is passed up food chains to label consumers up to the top predators. Within each biome, there is reasonable fidelity to the $\delta^{13}C$ observed in the primary producers and a predictable increase in the $\delta^{15}N$ with each known increase in trophic level. However, among individuals of each taxon analyzed, there are often large ranges in values, especially in the carbon isotope ratios.

A fundamental assumption in the employment of isotope ratios as natural tracers is that the amount of isotopic fractionation in the process of metabolizing food is known during the incorporation of assimilated components into the consumer. For marine mammals, these data are scarce and most of the ongoing work is based on the findings derived from terrestrial bird and mammal studies. The accurate interpretation of isotope ratio data on food webs and marine mammals depends completely on knowledge of fractionation effects arising from dietary sufficiency and composition. To date, we do not have this knowledge because it has become evident that there exist marked geographic gradients in isotope ratios in Prince William Sound and the Gulf of Alaska. This project is thus aimed at the goal of identifying specific biomarker molecules and acquiring accurate isotope fractionation data on harbor seals through controlled feeding and laboratory experiments. This project will be thoroughly integrated with ongoing

research on harbor seals at the ASLC and will be complementary to the physiological research projects in progress.

## NEED FOR THE PROJECT

### A. Statement of Problem

Harbor seals were undergoing an unexplained decline in numbers before the oil spill and the decline was further accelerated by the disaster. Since that time, the population has not recovered and is still at a low level, although now perhaps finally stabilized. No definitive cause and effect relationships have been found for the decline or failure to recover. It is becoming increasingly evident, however, that change in the marine environment in the past two decades has altered the carrying capacity downward in the northern Gulf of Alaska and the effects are being felt to the top of the food chains. Carbon isotope ratios in biota of the northern Pacific Ocean appear to have been declining for nearly twenty years (Schell, in preparation) and imply that a major decrease in productivity has occurred. Isotope ratios from wild seals also show changes over time in the isotope ratios but the interpretation requires knowledge of both the fractionation that occurs during assimilation and the natural variations arising from migrational movements. If one or more essential amino acids can be identified in the diet of seals, these would allow a conservative tracer independent of isotope fractionation effects. There are almost no data regarding marine mammals on this subject and none on harbor seals. This study will undertake to follow both the "whole animal" carbon and nitrogen isotopic fractionation and the determination of specific biomarkers arising from diet that would allow clearer insight into dietary dependencies.

### B. Rationale/Link to Restoration

Carbon isotope ratios serve as conservative tracers of energy supply between trophic levels (phytoplankton to zooplankton to fishes to top consumers). Seals, cetaceans, birds, etc. acquire the isotope ratios in proportion to the amount of food derived from each differing source. This, in turn, is reflected in the composition of body tissues and in keratinous tissues (claws, feathers, baleen, and whiskers) as a temporal record when multiple sources of food are consumed over time and space. This allows the discerning of important habitats and food resources in animals such as harbor seals that seasonally migrate or undergo periods of hyper- and hypotrophy. Little is known, however, of the internal fractionation of isotopes that occurs in mammals during fasting and/or extended periods of suboptimal diets. Currently planned experiments on the effects of differing diets on captive harbor seals conducted at the ASLC provide an ideal opportunity to enhance the physiological data gained by investigating the efficiency of amino acid transfers in diets and the presence of essential amino in pinnipeds.

Nitrogen isotope ratios reflect both the food sources and the trophic status of that animal. As nitrogen in food is consumed and assimilated by a consumer, the heavy isotope is enriched by approximately 3‰, with accompanying loss of the lighter isotope through excretion. The enrichment occurs with each trophic step and thus allows the construction of conceptual models and food webs and the assignment of relative trophic status to species for which dietary data are sparse. Hobson and Welch (1992) used isotope ratios to describe the trophic relationships of birds and mammals to the available prey species in the Canadian Arctic. Further extension to benthos by Dunton et al. (1991) and to fishes (Vinette, 1992) has confirmed that the isotopic

trends are evident across the entire food web. During fasting or starvation, nitrogen isotopes may be fractionated during transamination reactions leading to overall shifts in the average isotope ratios of the whole animal. Best and Schell (1996) observed, for example, that $^{15}N$ enrichment in southern right whales evidenced during winter breeding season in South African waters when carbon isotope ratios revealed that very little feeding occurred. Detailed interpretation of data from samples taken from wild seals requires that these effects be known.

### C. Location

The research effort will be conducted at the Alaska SeaLife Center and the University of Alaska Fairbanks. The instrumental analyses such as HPLC (high performance liquid chromatography) and gas chromatography-mass spectrometry will initially be undertaken at UAF on samples collected during the dietary studies and sampling at ASLC by Dr. Castellini's group. In years 2 and 3, more of the effort will be shifted to ASLC as detailed dietary experiments are conducted.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Much of the research will be conducted at the Alaska SeaLife Center and the Principal Investigator anticipates both community interaction and explanation of the research approach and usefulness at the site.

## PROJECT DESIGN

### A. Objectives

The null hypotheses to be tested in 1999-2000 and succeeding years are as follows:

1. The isotope ratios of harbor seals accurately reflect diet under all conditions. Increased fractionation does not occur during periods of fasting or suboptimal feeding and does not affect either carbon or nitrogen isotope ratios in harbor seals.

2. There are no essential amino acids in harbor seals and their prey that can act as conservative markers of specific habitats of food sources or of specific prey species.

The objectives of this study are divided into three elements:

1. Year 1, now underway, consists of developing methods and protocols for the isolation of metabolites from harbor seal blood and tissue samples to be employed during the following controlled diet studies. The Institute of Marine Science has purchased a new GC-IRMS (gas chromatograph–isotope ratio mass spectrometer) that will be used to determine isotope ratios in the individual amino acids isolated from serum samples. These amino acids will be separated by high performance liquid chromatography using semi-preparative columns and inorganic buffers. Testing for essential amino acids in harbor seals has been initiated using blood samples acquired from seals being used by Dr. Michael Castellini for food assimilation efficiency studies. By feeding $^{15}N$ and $^{13}C$-labeled glycine to the seals prior to blood sample collection, it will be evident if the label has been transaminated to all amino acids and to

what extent. If some amino acids remain unlabeled, the corresponding labeled amino acid will be administered to see if transamination occurs in the reverse direction.

2. The second component will be a study of the effects of suboptimal versus optimal diet on the fractionation of carbon and nitrogen isotopes in harbor seals. Diets of known amount and composition (isotopic and energetic) will be fed to the seals at ASLC, and blood protein amino acids will be monitored for composition and isotope ratios. This research is being closely coordinated with studies of controlled diet/assimilation efficiencies in harbor seals by Dr. M. Castellini so that minimal animal handling and sampling will be necessary. The feeding study began in December 1998 and is now continuing.

3. The third component will be to determine source prey for isotopically distinct fatty acids or other metabolites. The identification of specific fatty acids that carry a conservative signal to top consumers (birds, cetaceans, fissipeds) would yield an extraordinarily valuable tool to follow food web transfers or to identify specific habitat importance. This will be accomplished by the analysis of lipids in prey species from locations around the study areas and from seals. Many of the prey species samples are already archived and analysis can begin very soon.

## B. Methods

*Isotopic Analysis of Blood Protein Amino Acids*

The proteins in blood serum samples from captive harbor seals and muscle protein from native harvested seals will be separated from inorganic components via ion retardation columns and the isolated protein hydrolyzed to free amino acids. Multiple procedures to optimize amino preservation will be employed, such as acid and basic hydrolysis and through the use of proteolytic enzymes. Once isolated the free amino acids will be separated by HPLC, and the aliquots with individual amino acids will be taken to dryness. These samples will then be run on an elemental analyzer coupled to the isotope ratio mass spectrometer. The nitrogen and carbon dioxide liberated in the elemental analyzer will be separated by gas chromatography and run individually in the IRMS (isotope ratio mass spectrometer). We have intravenously dosed a seal with $^{15}$N-labeled glycine, and the appearance of the label will be noted over time in the amino acid spectrum. Those amino acids remaining free of the label will be identified as probable essential amino acids derived solely from diet. Mobilization and isotopic fractionation of these amino acids will be tested further in reverse dietary studies wherein the labeled amino acid will be infused and the rate of transamination followed in feeding and fasting seals. Although samples have been already collected, the analyses are not complete at this time.

*Isotope Fractionation During Fasting and Suboptimal Diets*

Many marine mammals undergo periods of fasting or suboptimal diets such as during molt or reproduction. Nothing is known regarding the effects of these periods on the fractionation of either carbon or nitrogen isotopes in harbor seal tissues. The amino acid threonine, for example, has been shown to become very isotopically depleted in $^{15}$N during starvation, with lesser effects on glycine and serine (Hare et al., 1991). In coordination with studies of dietary effects on blood hormones or other work requiring harbor seal blood samples at ASLC, we will analyze aliquots as described above for shifts in the isotope ratios. Mobilization of amino acids during fasting can be tested via isotope dilution of labeled amino acids given intravenously at the start of the fast. These experiments will be conducted in the second year of the experiment and will be carefully planned to minimize animal handling and for maximum synergy with other researchers.

Although we plan to coordinate our sampling with that of Dr. Castellini, all procedures will be approved by the ASLC scientific committee and conducted as required by the IACUC (Institutional Animal Care and Use Committee) of the University of Alaska and ASLC.

*Sources of Essential Amino Acids in the Diets of Harbor Seals*
The identification of specific metabolites, specifically fatty acids and amino acids, in the tissues of harbor seals will be followed by a survey of potential prey species to identify probable sources. Fatty acids will be isolated using the procedures of Iverson et al. (1993) and run from the gas chromatograph directly into the microcombustion unit of the preparatory system and then into the mass spectrometer. This will yield both a fatty acid spectrum and the isotope ratios for each component. The combination of chemical markers may provide a powerful tool for the identification of specific prey or habitat usage. The APEX program currently supported by EVOS will be a source of samples, as will other opportunistic cruises in the spill and control areas. Herring, sand lance, pollock and capelin will be special targets, given their importance in the food chains of Prince William Sound.

In order to strengthen the expertise in biochemistry and to provide a comprehensive internal review of planned experiments, the following steps were implemented:

The P.I. has accepted Ms. Liying Zhao as Ph.D. candidate to undertake the experimentation on this project. Ms. Zhao has an exceptionally strong background in chemistry and has excellent grades and recommendations by her professors. Her past curriculum has been heavily weighted to organic and analytical chemistry and she has completed introductory study in biochemistry. She is planning on continuing her courses in biochemistry during this study. She is currently developing the HPLC methodologies and purification procedures for the amino acids.

In response to the request for additional biochemistry, nutrition and metabolism expertise, a graduate advisory committee has been formed for Ms. Zhao that has a strong emphasis on these disciplines. Dr. D. M. Schell, as PI, will be committee chair and will provide the primary expertise in stable isotope usage and interpretation of isotope ratio data. The following UAF faculty members have agreed to comprise the rest of the graduate committee and assist in experimental design and review of biochemical data:

Dr. Michael Castellini, Professor of Marine Science, has his background in biochemistry and is currently involved in studies of marine mammal nutrition at the ASLC.
Dr. Larry Duffy, Professor of Biochemistry and Chemistry, is the current Head of the Chemistry and Biochemistry Program.
Dr. Susan Henrichs, Professor of Marine Science, is a chemist specializing in the microbial biochemistry of amino acids in marine environments.
Dr. Bruce Finney, Professor of Marine Science is experienced with the environmental aspect of ocean chemistry and stable isotope methodology.

As the graduate advisory committee for Ms. Zhao, the above committee will aid in experimental design and review of protocols as well as assist with whatever difficulties may arise with the analytical aspects of the study.

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

M. Castellini is concurrently working on Project 99341 for related work on blood hormones and food assimilation efficiency studies at the Alaska SeaLife Center. This project will be completely coordinated with his work to optimize sampling and mutual assistance.

## SCHEDULE

### A. Measurable Project Tasks for FY 00 (October 1, 1999–September 30, 2000)

*FY 00*

| | |
|---|---|
| October - February: | Continue amino acid analyses and coordinate with feeding trials. |
| March - July: | Continue analytical work; if necessary implement alternate amino acid analysis via gas chromatography and derivatives. |
| September – December 00: | Analytical work, begin fatty acid study. |

### B. Project Milestones and Endpoints

The following are additional specific goals beyond FY 99:

*FY 00*

| | |
|---|---|
| November - August: | Isolate amino acids from prey species and establish isotope ratios in any essential amino acids identified; prepare Annual Report on FY 00 (and prior) work. |
| August - December: | Conduct feeding experiments, prepare draft manuscripts. |

*FY 00 - FY 01*

| | |
|---|---|
| October - May: | Complete experiments; synthesize data and identify gaps; prepare manuscripts and submit draft Final Report. |
| June – October | Complete manuscripts and Final Report. |

### C. Completion Date

This project will be completed by September 2001. Manuscript preparation and submissions may continue past the nominal completion date.

## PUBLICATIONS AND REPORTS

Results of this project will be made available via the following:

*Annual Reports*: These reports will detail progress and preliminary findings and notable achievements. The annual report due April 1999 (six month progress) is submitted with this proposal and the next annual report will be submitted in April 2000.

*Final Report*: A Final Report will be provided. Technical results in this report will be shared with EVOS collaborators and assistance provided as opportune during the experiments. Preliminary exchange of findings will be conducted with EVOS investigators and the scientific community via professional meetings and informal communications.

*Peer-reviewed publications*: Over the course of this study peer-reviewed publications will be generated for the open literature based on the scientific findings. These publications will be generated by the PI and graduate students as first author publications when the primary focus is on the findings produced by the isotopic techniques or as second author publications when the isotope work is a minor part of other scientific results resulting from feeding experiments conducted by colleagues.

*Papers at scientific society meetings*: We request support for travel to appropriate scientific meetings for dissemination of results and interaction with colleagues. It is anticipated that the PI and a graduate student will attend the Society for Marine Mammalogy and/or the American Society for Limnology and Oceanography meetings.

*Public lectures*: Interaction with the public will arise through formal and informal presentation of results as part of ongoing public participation in the work at ASLC. Synthesis meetings designed to explain the findings will be presented at meetings coordinated by ASLC or EVOS and open to the public. Informal presentation of results will occur through interaction with interested members of the public, press and scientific community. Classroom instruction will also involve integration of findings into the presentation of educational material.

## PROFESSIONAL CONFERENCES

The results of this project will be communicated at appropriate meetings. The biennial meeting of the Society for Marine Mammalogy or the American Society for Limnology and Oceanography is typical for this type of presentation, as are specific workshops and meetings emphasizing application of isotope techniques to biological problems. The next biennial marine mammal meeting is in Hawaii in December 1999, and if sufficient new data are available, this meeting will be attended. Otherwise a presentation will be made at a later meeting.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Resources and Services – This study focuses on harbor seals in Prince William Sound and requires the facilities for animal holding at the Alaska SeaLife Center. Insofar as the PI is requesting no seal handling or holding support in this project, it is essential that it be closely coordinated with ongoing projects that can provide subsamples of blood or biopsies for analysis. To this end, the PI has made the project outline and goals available to Dr. Castellini and presumes a very close interaction with his program. The Ph.D. student supported by this project has been integrated with Dr. Castellini's project and will continue to share time and assistance with his project team. We seek to provide a set of useful biomarker tools that will aid future field efforts in Prince William Sound and can be expanded to other injured species. Although the major effort is concerned with harbor seals, other marine mammal tissues will be analyzed if available to provide context and comparable data. Sea lions held at ASLC will also be sampled if conditions allow and funds are derived from other sources. To simplify animal use and care

permitting, we will coordinate all permitting closely with the projects under the direction of Dr. Michael Castellini through mutual interests and animal handling requirements.

## PROPOSED PRINCIPAL INVESTIGATOR

Donald M. Schell
Institute of Marine Science
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, AK 99775-7220
Phone: (907) 474-7115
Fax: (907) 474-7204
E-mail: schell@ims.alaska.edu

## PRINCIPAL INVESTIGATOR

D. M. Schell has been involved in stable isotope studies for over 25 years. His research has included natural abundance tracer studies and enrichment experiments. His work on bowhead whales and geographic gradients in stable isotope ratios has been published and subjected to rigorous reviews. The findings have been upheld and have provided insight into bowhead whale natural history unattainable by other techniques.

Dr. Schell oversees the stable isotope ratio mass spectrometry facility on the UAF campus. This consists of three working instruments that are dedicated to specific elements, as demand requires. A Europa automated continuous flow system will be used for most samples but back-up analytical capability is available. A new machine has recently been installed that has the ability to determine isotope ratios on individual fatty acids and on derivatized amino acids. This machine will expand the sample analysis capability and provide increased sensitivity for small samples.

As PI, Schell will oversee the Quality Assurance/Quality Control aspects of this project. Protocols for sampling have been established and working standards are cross calibrated with other nationally recognized laboratories.

## OTHER KEY PERSONNEL

Machine operations are the responsibility of Norma Haubenstock, technician. She is well trained and has more than nine years experience with mass spectrometers. Additional funds are budgeted for an assistant to prepare samples, load and operate the automated system and to aid in data processing and archiving for all users. A Ph.D. student will also be included in the project.

## LITERATURE CITED

Best, P.B. and D. M. Schell. 1996. Stable isotopes in southern right whale (*Eubalaena australis*) baleen as indicators of seasonal movements, feeding and growth. *Mar. Biol.* 124:483-494

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Iverson, S.J., K. J. Frost and L. F. Lowry. (in press) Fatty acid signatures reveal fine scale structure of foraging distribution of harbor seals and their prey in Prince William Sound, Alaska. *Mar. Ecol. Prog. Ser.*

Michener, R.H. and D.M. Schell. 1994. The use of stable isotopes in tracing marine aquatic food webs. *In:* R. Michener and K. Ljatha (eds.), *Stable Isotopes in Ecology and Environmental Research*, p. 138–157. Blackwell Scientific, Cambridge.

Saupe, S.M., D.M. Schell and W.B. Griffiths. 1989. Carbon-isotope ratio gradients in western arctic zooplankton. *Mar. Biol.* 103:427–432.

Schell, D.M. 1997. Whale baleen provides a multi-year record of primary productivity in the Bering Sea. (Abstract) Amer. Soc. Limnol. Oceanogr. Santa Fe, NM, 10–14 Feb., p. 296.

Schell, D.M., S.M. Saupe and N. Haubenstock. 1989. Bowhead whale (*Balaena mysticetus*) growth and feeding as estimated by techniques. *Mar. Biol.* 103: 433–443.

Vinette, K.A. 1992. Carbon and nitrogen isotope ratios in bowhead whales and their zooplankton prey as indicators of feeding strategy and environmental change. M.S. Thesis, University of Alaska Fairbanks. 147 p.

**2000 EXXON VALDEZ TF EE COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $98.0 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $98.0 |
| General Administration | | $6.9 |
| Project Total | $0.0 | $104.9 |
| Full-time Equivalents (FTE) | | 1.4 |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | | Estimated FY 2001 | Estimated FY 2002 | | |
| | | $96.3 | | | |

Dollar amounts are shown in thousands of dollars.

Other Resources

Comments:

**FY00**

Prepared:

Project Number: 00371
Project Title: Effects of Harbor Seal Metabolism on Stable Isotope Ratio Tracers
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

## 2000 EXXON VALDEZ TF EE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $60.1 |
| Travel | | $6.1 |
| Contractual | | $9.8 |
| Commodities | | $2.4 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $78.4 |
| Indirect | | $19.6 |
| Project Total | $0.0 | $98.0 |
| Full-time Equivalents (FTE) | | 1.4 |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| | | Estimated FY 2001 | Estimated FY 2002 | | |
|---|---|---|---|---|---|
| | | $90.0 | | | |

Dollar amounts are shown in thousands of dollars.

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 $5,868 per year.

**FY00**

Prepared:

Project Number: Project Number: 00371
Project Title: Effects of Harbor Seal Metabolism on Stable Isotope Ratio Tracers
Name: Donald M. Schell

FORM 4A
Non-Trustee
SUMMARY

## 2000 EXXON VALDEZ TR EE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 2000 |
| Schell, D. | Principal Investigator/Director, IMS | | 2.0 | 12.0 | | 24.0 |
| Haubenstock, N. | Technician | | 3.0 | 5.3 | | 15.9 |
| TBN | Ph.D. Student | | 12.0 | 1.7 | | 20.4 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | Adjustment for rounding error | | | -0.2 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 17.0 | 19.0 | 0.0 | |
| | | | | | **Personnel Total** | $60.1 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| Description | | Price | Trips | Days | Per Diem | FY 2000 |
| Fairbanks to national meeting | | 1.1 | 1 | 8 | 120.0 | 2.1 |
| Fairbanks to Anchorage | | 0.3 | 1 | 5 | 120.0 | 0.9 |
| Fairbanks to Seward | | 0.4 | 2 | 20 | 120.0 | 3.1 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $6.1 |

**FY00**

Prepared:

Project Number: Project Number: 00371
Project Title: Effects of Harbor Seal Metabolism on Stable Isotope Ratio Tracers
Name: Donald M. Schell

FORM 4B
Personnel
& Travel
DETAIL

| Contractual Costs: | Proposed |
|---|---|
| Description | FY 2000 |
| Mass spectrometry | 9.0 |
| Publications, page charges | 0.6 |
| Communications, photocopying | 0.2 |
| **Contractual Total** | $9.8 |

| Commodities Costs: | Proposed |
|---|---|
| Description | FY 2000 |
| FID detector, chemicals, expendables | 2.2 |
| Computer software | 0.2 |
| **Commodities Total** | $2.4 |

**FY00**

Project Number: Project Number: 00371
Project Title: Effects of Harbor Seal Metabolism on Stable Isotope Ratio Tracers
Name: Donald M. Schell

FORM 4B
Contractual & Commodities DETAIL

Prepared:

2000 EXXON VALDEZ TI EE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

| 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 |
| 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 | |
|---|---|---|
| | | |

FY00

Project Number: Project Number: 00371
Project Title: Effects of Harbor Seal Metabolism on Stable Isotope Ratio Tracers
Name: Donald M. Schell

FORM 4B
Equipment
DETAIL

Prepared:

00372


# Native Village of Eyak

P.O. Box 1388
Cordova, AK 99574
907-424-7738 Fax 907-424-7739


April 15, 1999

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

Dear Molly:

Enclosed is a restoration proposal to monitor Stellar Sea Lions in the Prince William Sound/Copper River area. As the Stellar Sea Lions have been placed on the endangered list by NMFS, it is critical that we find out the reason for their demise. Should the decline in the Sea Lion numbers continue, the subsistence harvest of salmon, herring and other marine life will be curtailed.

As a Tribal Council, we are requesting technical assistance from EVOS for this proposal.

Sincerely yours

Bob Henrichs
President
Native Village of Eyak
Traditional Council

**Stellar Sea Lion Monitoring Project**

| | |
|---|---|
| Project Number: | 00372 |
| Restoration Category: | Enhance/Replace Subsistence Resources |
| Proposer: | Native Village of Eyak |
| Lead Trustee Agency: | Native Village of Eyak, a Federally Recognized Tribal Government |
| Cooperating Agencies: | DOI, ADFG, NMFS & CRRC |
| Duration: | 1st year of a five year project. |
| Cost FY 00: | $263.2 |
| Cost FY 01: | $276.4 |
| Cost FY 02: | $290.2 |
| Cost FY 03 | $304.7 |
| Cost FY 04: | $319.9 |
| Geographic area: | Copper River, Prince William Sound. |
| Injured Resource/Service: | Subsistence |

Abstract:

Stellar Sea Lions are on the decline and have been placed on the endangered list by NMFS. If this trend continues, subsistence fishing for salmon, herring and other marine life will be curtailed. Some traditional areas may be closed to all fishing and hunting. We need to monitor the interaction between the Stellar Sea Lions and the fishing fleets. This proposal would fund this interaction.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Native Village of Eyak | | | | | | | | |
| | Exxon Valdez Oil Spill Trustees Council | | | | | | | | |
| | Stellar Sea Lion Monitoring Project | | | | | | | | |
| | **Budget Summary** | | | | | | | | |
| Budget Category | Authorized FY 99 | Proposed FY 00 | | | | | | | |
| Personnel | | 146,899 | | | | | | | |
| Travel | | 6,018 | | | | | | | |
| Contractual | | 29,050 | | | | | | | |
| Commodities | | 11,116 | | **Long Range Funding Requirements** | | | | | |
| Equipment | | 13,256 | | | | | | | |
| Other | | 4,212 | | | | | | | |
| Subtotal | | 210,551 | Estimated | Estimated | Estimated | Estimated | | | |
| Indirect | | 52,638 | FY 2001 | FY 2002 | FY 2003 | FY 2004 | | | |
| Budget Total | 0 | 263,189 | 276,350 | 290,166 | 304,675 | 319,910 | | | |
| Full-Time Equivalent (FTE) | | 3.0 | 4.00 | 4.00 | 4.00 | 4.00 | | | |
| | | | Native Village of Eyak | | | | | | |
| | | | Exxon Valdez Oil Spill Trustees Council | | | | | | |
| | | | Stellar Sea Lion Monitoring Project | | | | | | |
| | | | **Budget Detail Narrative** | | | | | | |
| **Salaries:** | | | | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| Project Lead Biologist | The project lead biologist will work to research past trends on Sea Lion Populations and coordinate with fishermen on data gathering plan. | | | | | | | | |
| | Project Biologist: | 1 FTE @ | 70,500 | | 70,500 | 74,025 | 77,726 | 81,612 | 85,693 |
| | | | | | (1 FTE) | (1 FTE) | (1 FTE) | (1 FTE) | (1 FTE) |
| Fisheries Technicians | One full time research technician will be needed to assist with the project and implement the project. | | | | | | | | |
| | Research Technicians | 1 FTE @ | 39,950 | | 39,950 | 41,948 | 44,045 | 46,247 | 48,559 |
| | | | | | (1 FTE) | (1 FTE) | (1 FTE) | (1 FTE) | (1 FTE) |
| **Total Salaries** | | | | | 110,450 | 115,973 | 121,771 | 127,859 | 134,252 |
| **Fringe:** | | | | | | | | | |
| FICA | | 6.20% | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Medicare | | 1.45% | | | | | | | |
| FUTA | | 0.60% | | | | | | | |
| Alaska ESC | | 3.50% | | | | | | | |
| Workman's Comp. | | 5.25% | | | | | | | |
| Medical, Dental Vision benefits | | 16.00% | | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| | | | | | | | | | |
| Budgeted Fringe: | | 33.00% | of salary. | | 36,449 | 38,271 | 40,184 | 42,193 | 44,303 |
| | | | | | | | | | |
| **Budgeted Personnel** | | | | | 146,899 | 154,244 | 161,955 | 170,052 | 178,555 |
| | | | | | | | | | |
| **Travel:** | | | | | | | | | |
| Travel will be needed to gather to discuss the project and prepare the restoration plan and implement the work | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| | | | | | | | | | |
| Lead Biologist Travel to meetings, and professional conferences | | | | | 3762 | | | | |
| Research Technician Travel to conduct project | | | | | 2,043 | | | | |
| Council Travel and Public Involvement Hearings | | | | | 3,975 | | | | |
| | | | | | | | | | |
| **Budgeted Travel:** | | | | | 6,018 | 6,319 | 6,635 | 6,967 | 7,315 |
| | | | | | | | | | |
| **Contractual** | | | | | | | | | |
| | | Hours | Cost/Hr. | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| | | | | | | | | | |
| Scientific review and consultation on planning | | 100 | 85 | | 8,500 | 8,925 | 9,371 | 9,840 | 10,332 |
| and project design | | | | | | | | | |
| | | | | | | | | | |
| Vessel Charter | | 190 | 95 | | 18,050 | 18,953 | 19,901 | 20,896 | 21,941 |
| | | | | | | | | | |
| Data Reporting Stipend ($25/participant 100 participants) | | | | | 2,500 | 2,625 | 2,756 | 2,894 | 3,039 |
| | | | | | | | | | |
| **Budgeted Contractual:** | | | | | 29,050 | 30,503 | 32,028 | 33,630 | 35,312 |
| | | | | | | | | | |
| **Commodities:** | | | | | | | | | |
| | | | | | | | | | |
| Supplies will be needed to accomplish the project. Office supplies, filing supplies, and | | | | | | | | | |
| presentation media will be required to track data and project information, products and materials. | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | Cost Per Month | Months Needed | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| | | | | | | | | | |
| Office Supplies, filing, data and other. | | 162 | 12 | | 1,944 | 2,041 | 2,143 | 2,250 | 2,363 |
| | | | | | | | | | |
| Project Field Supplies, Tags and Materials | | 2,293 | 4 | | 9,172 | 9,631 | 10,113 | 10,619 | 11,150 |

ar

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Budgeted Commodities:** | | | | | 11,116 | 11,572 | 12,256 | 12,869 | 13,513 |
| | | | | | | | | | |
| **Equipment:** | | | | | | | | | |
| | | | | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| | | | | | | | | | |
| Testing and monitoring recording devices, lab and measurement equipment | | | | | 8,763 | 9,201 | 9,661 | 10,144 | 10,651 |
| Computer Equipment | | | | | 4,493 | 4,718 | 4,954 | 5,202 | 5,462 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| **Budgeted Equipment:** | | | | | 13,256 | 13,919 | 14,615 | 15,346 | 16,113 |
| | | | | | | | | | |
| **Other:** | | | | | | | | | |
| | | | | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| | | Cost Per Month | Months Needed | | | | | | |
| | | | | | | | | | |
| Phone, fax, copies, office and lab space | | 351 | 12 | | 4,212 | 4,423 | 4,644 | 4,876 | 5,120 |
| | | | | | | | | | |
| **Budgeted Other:** | | | | | 4,212 | 4,423 | 4,644 | 4,876 | 5,120 |
| | | | | | | | | | |
| **Total Direct Costs:** | | | | | 210,551 | 221,080 | 232,133 | 243,740 | 255,929 |
| | | | | | | | | | |
| Indirect: | | | | | | | | | |
| Indirect is computed at our negotiated rate of 25%. | | | | | | | | | |
| | | | | | Proposed FY 00 | 2001 | 2002 | 2003 | 2004 |
| | | | | | | | | | |
| **Budgeted Indirect Costs:** | | | | | 52,638 | 55,270 | 58,033 | 60,935 | 63,982 |
| | | | | | | | | | |
| **Total Costs** | | | | | 263,189 | 276,350 | 290,166 | 304,675 | 319,910 |

# Effect of *Exxon Valdez* oil spill on herring spawning locations and use of nursery areas

| | |
|---|---|
| Project Number: | 00373 |
| Restoration Category: | Research |
| Proposer: | University of Alaska Fairbanks |
| Lead Trustee Agency: | ADF&G |
| Cooperating Agencies: | none |
| Alaska Sea Life Center: | no |
| Duration: | 1st year, 1-year project |
| Cost FY 00: | $44,680 |
| Cost FY 01: | 0 |
| Cost FY 02: | 0 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | Pacific herring |



## ABSTRACT

The proposed research will study the importance of the two factors that were identified by the SEA herring program as critical steps to successful recruitment, i.e., the effect of herring spawning location and the effect of how the larvae are distributed. Using physical circulation modeling of PWS developed under SEA, climate scenarios that result in herring larvae being transported from spawning locations to nursery areas will reveal which areas are most likely to retain herring larvae in PWS in locations conducive to successful development as juveniles. This technique also will show the potential effect on herring spawned or distributed within the spill area.

## INTRODUCTION

The *Exxon Valdez* oil spill occurred one week before Pacific herring (*Clupea pallasi*) started to spawn in Prince William Sound in spring 1989. Direct effects of the oil on herring in 1989 have been shown (Brown et al., 1996a & b; Hose et al., 1996; McGurk and Brown, 1996; Norcross et al., 1996). Subsequently the herring population crashed due to viral hemorrhagic septicemia virus (VHSV) and the fishery was closed in 1993. A connection has been shown between the outbreak of VHSV and the presence of oil (Carls et al., 1998). At the March 1999 10th Anniversary EVOS symposium Richard Kocan presented evidence that crowding of herring, especially at early ages, affects the transmission of VHSV (Kocan et al., 1999). Furthermore, at the same meeting, Kevin Stokesbury showed calculations which explained the crash of the herring fishery based on crowded distribution and resultant year-class failure (Stokesbury, 1999). Stanley Rice discussed the toxic persistence of oil in the near-shore environment of PWS and its affect on survival of salmon (Rice, 1999). Chris Kennedy revealed that the chronic stress of exposure to oil can cause physiological problems or even death in juvenile herring (Kennedy and Farrell, 1999).

The SEA program studied the life history of herring, concentrated on the early life stages (\320-T) and presented the synthetic results of herring life history at the EVOS meeting (Norcross et al., 1999). Those results revealed multiple points in the early life history of herring that are vulnerable to stressors. Two of the vulnerable periods that could result in a poor year class are spawning and larval stages, specifically, spawning location/timing and larval dispersal/timing. These are the same stages at which exposure to oil or VHSV causes problems.

ADF&G has surveyed five areas, North Shore, Naked Island, Northeast Shore, Southeast Shore and Montague Island, for herring spawning since 1973. Of those, Naked and Montague Islands were directly in the path of the EV oil, and the others were impacted less directly. Bays throughout the sound, which have been determined by SEA research (\320-T) to act as herring nursery areas, were affected by the oil in 1989 and may still contain oil. Thus, it is important to investigate the patterns of herring spawning and larval dispersal to bays in relation to the distribution of oil.

We propose to build upon knowledge of herring life history (\320-T) and physical oceanography of PWS (\320-J) learned during the SEA investigations to examine these vulnerable life stages. We will use a physical model of circulation within PWS coupled with spawning location of herring to determine to which nursery areas larval herring will be transported. To make this applicable beyond the years of the oil spill and VHSV we will model general circulation patterns within PWS in combination with general spawning distribution patterns to produce scenarios of expected distribution of larvae for all combinations. The results will be presented in such a way that they can be easily used in future years.

## NEED FOR PROJECT

### A. Statement of Problem

Pacific herring are listed as a recovering resource. Much research has already been conducted on herring that has provided insight as to the causes of decline of the species and conditions necessary for it to recover. While we cannot directly restore the herring population size or its health, we can investigate specific impediments that prevent this recovery. Demonstration of modeled results of various combinations of herring spawning locations and physical transport processes will help elucidate the importance of these factors.

### B. Rationale/Link to Restoration

The proposed project builds upon results from two components of the SEA project, juvenile herring (\320-T) and modeling of physical oceanography (\320-J). We will use the physical oceanographic model developed under SEA to examine the importance of two of the vulnerable periods in the life history of herring that were identified as part of the SEA project (spawning and larval stages). The results from each of these components were necessary to identify the hypothesized link with the impact of the oil on herring recruitment success. Knowledge of this link, in relation to other factors that potentially impact herring recruitment success (Norcross et al., in prep.), will improve the understanding of herring recruitment success and will be valuable to managers of herring.

### C. Location

The modeling proposed will be for PWS only.

## COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

The background knowledge on which this proposal is based was collected and analyzed as part of the SEA project, including herring (\320-T), physical oceanography (\320-J) and local and traditional ecological knowledge (\320-T Supplement). During those projects, local commercial fishing vessels were hired, local Cordovans were employed, and purchases were made locally in Cordova. The results of this project will be made available through public media to residents of PWS. We will communicate our results directly to local herring fisheries managers.

## PROJECT DESIGN

### A. Objectives

The research objectives of this project are:

1. To model distribution of herring larvae dependent upon climatic/oceanographic scenarios and location of herring spawning.

2. To analyze those results with respect to potential effect on successful recruitment of juvenile herring.

3. To show the potential impact of the oil spill on herring spawned or distributed within the spill area in 1989 and later years.

### B. Methods

We will use a physical oceanographic model for four generalized climate regimes to develop scenarios of dispersal of herring larvae from five spawning locations.

We hypothesize that not all combinations of climate/oceanography and locations of herring spawning result in equally good dispersal of herring larvae. Under some combination of conditions, more larvae will be lost from PWS. Under other combinations of conditions, most larvae will be transported to the same place. This would result in crowding (potential for VHSV) and competition for food (identified by SEA \320-T) within nursery areas, both of which are bad for survival and recruitment of juvenile herring. Still other conditions should result in dispersal of herring larvae around PWS to a variety of suitable nursery areas.

In order to test this hypothesis, we will examine herring spawned from the five areas which ADF&G surveys for herring spawning, North Shore, Naked Island, Northeast Shore, Southeast Shore and Montague Island. We will also examine the general climate/oceanographic scenarios identified under SEA. For the SEA years 1994-1998, the spring climate/oceanographic regime fell in two broad categories: "cold/windy" or "warm/calm" (\320-R; Eslinger et al., 1999). Prior to that time, the spring oceanography appeared to manifest as a "river" or a "lake" (Cooney 1997). We will use a combination of the five spawning sites and four circulation regimes to produce models of twenty scenarios depicting distribution of herring larvae within PWS. Each scenario will be a combination of one spawning region and one climate regime.

The first level of physical oceanographic models of circulation in PWS were developed under SEA project \320-J by Dr. Christopher N.K. Mooers and colleagues (Wang et al., 1997; Deleersnijder et al., 1998; Mooers and Wang, 1998). Continued refinements of the model are being made under separate funding to C.N.K. Mooers (University of Miami) from the Oil Spill Recovery Institute (OSRI). If continued refinement of the physical

model generates a more specific model or a different climate regime than one of the four described above, the newer information will be used in this project. Thus, at no cost to the proposed project, Dr. Mooers will produce the physical models for circulation within PWS, which are the basis of this project. Norcross will analyze the past spawning locations of herring using ADF&G data to determine the starting parameters for the models.

We will analyze the results of these twenty scenarios statistically using an ANOVA-type of analysis by first examining what percent of larvae are retained within PWS and comparing the difference among the scenarios. For each of the twenty scenarios of dispersal, we will examine evenness of dispersal. This will provide insight into potential crowding and competition within nursery areas. The results of these analyses will reveal how important a particular region of herring spawning or a particular climate regime is to the recruitment process. Norcross will perform all statistical analyses on results.

We will further analyze these results with regard to overlap with distribution of oil in 1989 and consider how the oil directly impacted spawning locations and nursery areas in 1989 and succeeding years. In concert with results from other EVOS studies (Carls et al., 1998; Rice, 1999; Kennedy and Farrell, 1999), we will examine the modeled distribution of herring larvae to investigate the potential impacts of oil on herring recruitment success. We believe we will be able to integrate results of these various EVOS studies to determine where herring nursery areas were impacted, and may continue to be to affected, by the presence of oil.

The hypothesis to be tested is a direct outcome of attendance by the PI at the recent 10$^{th}$ Anniversary EVOS Symposium coupled with the PI's knowledge of herring and physical models available for PWS. Modeling is the only way to reproduce the past and forecast the future. Thus, the modeling approach suggested here is the simplest, most direct way to clarify the importance of spawning location and larval dispersal on successful recruitment of herring juveniles and to simultaneously examine the effects of the oil spilled from the *Exxon Valdez*.

Norcross and Mooers will work together on production and analysis of the model results. Because of the close collaboration necessary between investigators, funds for four trips between Alaska and Florida are requested in the budget. The travel between Fairbanks and Miami is requested because the nature of the model makes it easier to discuss in person than electronically. Initially Mooers will explain the model to Norcross who will supply initial herring parameters. After several runs, Mooers and Norcross will discuss results and make adjustments as necessary. In the final stages, latest model developments will be discussed and incorporated if appropriate. Finally, Mooers and Norcross need to discuss interpretation of model results and begin the manuscript writing process. Further drafts and completion of the manuscript will be done electronically.

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

The University of Alaska Fairbanks is the only entity requesting funds in this proposal. Dr. Christopher N.K. Mooers of the University of Miami will make significant contributions. Collaboration with scientists at Prince William Sound Science Center will be ongoing throughout the project. Results will be shared with herring biologists at ADF&G in Cordova.

## SCHEDULE

### A. Measurable Project Tasks for FY ) (October 1, 1999 – September 30, 2000)

| | |
|---|---|
| December 31: | Determination of input parameters for herring |
| January 18-28 (3 of these days): | Attend Annual Restoration Workshop |
| January 1 – 31 March: | Meeting of PI's to begin model process |
| February 1 – July 1: | Run models |
| July 1 – August 31: | Analysis of model results |
| 1 – 30 September: | Write manuscript for peer-reviewed journal. |

### B. Project Milestones and Endpoints

| | |
|---|---|
| 1 July: | Objective 1: model distribution of herring larvae |
| 30 September: | Objectives 2 & 3: analyze model results |

### C. Completion Date

30 September 2000

## PUBLICATIONS AND REPORTS

Final Report (April 15, 2001)

Implications for recruitment of Pacific herring from modeled dispersal of larvae within Prince William Sound. B.L. Norcross and C.N.K. Mooers. *Fisheries Oceanography.*

## PROFESSIONAL CONFERENCES

No professional conferences will be attended, because we do not anticipate sufficient results of this project will be available until near the end of the contract period.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will address questions raised from previous and ongoing Restoration projects about vulnerable life stages of herring. As described above, interpretation of the results with regard to the impact of the oil spill will depend on written results of other EVOS

funded projects. We will coordinate the results of this focused research with that proposed by Evelyn Brown and Brenda Norcross (00375), which takes a broader view of herring recruitment and incorporates many factors, including more general aspects of the ones addressed here. We will also coordinate the results of this research with that proposed by Brenda Norcross (00374) which follows further in the life stage of herring and incorporates the specific results of herring in bays.

## PROPOSED PRINCIPAL INVESTIGATOR

Brenda L. Norcross
University of Alaska Fairbanks
Institute of Marine Science
School of Fisheries and Ocean Sciences
Fairbanks, AK 99775-7220
Phone: 907-474-7990
Fax: 907-474-1943
E-mail: norcross@ims.alaska.edu

## PRINCIPAL INVESTIGATOR

Dr. Brenda L. Norcross has been an EVOS investigator on the SEA herring project (\320T) since 1995. She also studied dispersal of herring larvae in PWS in 1989 under earlier EVOS funding (Norcross and Frandsen, 1996; Norcross et al., 1996). As such, she is uniquely qualified to determine the input necessary to run the physical model as well as to interpret the results.

## OTHER KEY PERSONNEL

Dr. Christopher N.K. Mooers has been an EVOS investigator on the SEA modeling project (\320-J) since 1994. He has adapted the Princeton Ocean Model for use in Prince William Sound. He has worked with Dr. Norcross in the past regarding modeled larval transport of herring larvae in PWS (Norcross et al., in prep.). Dr. Mooers is funded through OSRI to continue development of the physical model and has agreed to work with Dr. Norcross at no cost to the project other than travel time for collaboration.

## LITERATURE CITED

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Brown, E.D., T.T. Baker, J.E. Hose, R.M. Kocan, G.D. Marty, M.D. McGurk, B.L. Norcross, and J. Short. (1996b) Injury to the early life history stages of Pacific herring in Prince William Sound after the *Exxon Valdez* Oil Spill. *Am. Fish. Soc. Symp.* No. **18**: 448-462.

Carls, M.G., G.D. Marty, T.R. Meyers, R.E Thomas, and S.D. Rice. (1998) Expression of viral hemorrhagic septicemia virus in prespawning Pacific herring (*Clupea pallasi*) exposed to weathered crude oil. *Can J. Fish. Aquat. Sci.* **55**:1-10.

Cooney, R.T. (1997) Sound Ecosystem Assessment (SEA): an integrated science plan for the restoration of injured species in Prince William Sound, Alaska, *Exxon Valdez* Oil Restoration Project Annual Report (Restoration Project 96320), Alaska Department of Fish and Game, Habitat and restoration Division, Anchorage, Alaska.

Deleersnijder, E., J. Wang, and C.N.K. Mooers. (1998) A two-compartment model for understanding the simulated three-dimensional circulation in Prince William Sound, *Alaska. Cont. Shelf Res.* **18**:279-287.

Eslinger, D. L., R.T. Cooney, C.P. McRoy, P. Simpson, A. Ward, K.O. Coyle, J. Wang, T.C. Kline, S.L. Vaughan, J.R. Allen, J. Kirsch, and L.B. Tuttle. (1999) Observed and modeled plankton dynamics in Prince William Sound, Alaska. 10th Anniversary *Exxon Valdez* Oil Spill Symposium, Anchorage, AK, March 1999.

Hose, J.E., M.D. McGurk, G.D. Marty, D.E. Hinton, E.D. Brown, and T.T. Baker. (1996) Sublethal effects of the *Exxon Valdez* oil spill on herring embryos and larvae: morphologic, cytogenetic, and histopathological assessments, 1989-1991. *Can. J. Fish. Aquat. Sci.* **53**: 2355-2365.

Kennedy, C.J. and A. Farrell. (1999) Survival, performance, and reproduction in Pacific herring (Clupea harengus pallasi): Effects of environmental contamination, viral hemorrhagic septicemia virus, and *Ichthyophonus hoferi.* 10th Anniversary *Exxon Valdez* Oil Spill Symposium, Anchorage, AK, March 1999.

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McGurk, M.D. and E.D. Brown. (1996) Egg-larval mortality of Pacific herring in Prince William Sound, Alaska, after the *Exxon Valdez* oil spill. *Can. J. Fish. Aquat. Sci.* **53**(10): 2343-2354.

Mooers, C.N.K. and J. Wang. (1998) On the implementation of a three-dimensional circulation model for Prince William Sound, Alaska. *Cont. Shelf Res.*, **18**:253-277.

Norcross, B.L., E.D. Brown, R.J. Foy, M. Frandsen, S. Gay, M. Jin, T.C. Kline, J. Kirsch, D.M. Mason, C.N.K. Mooers, E.V. Patrick, A.J. Paul, K.D.E. Stokesbury, S.J. Thornton, S.L. Vaughan, and J. Wang. (In preparation) Early life history of herring in Prince William Sound. *Fish. Oceanogr.*

Norcross, B.L., E.D. Brown, R.J. Foy, M. Frandsen, S. Gay, M. Jin, T.C. Kline, J. Kirsch, D.M. Mason, C.N.K. Mooers, E.V. Patrick, A.J. Paul, K.D.E. Stokesbury, S.J. Thornton, S.L. Vaughan, and J. Wang. (1999) Life history of herring in Prince William Sound, Alaska. 10th Anniversary *Exxon Valdez* Oil Spill Symposium, Anchorage, AK, March 1999.

Norcross, B.L. and M. Frandsen. (1996) Distribution and abundance of larval fishes in Prince William Sound, Alaska during 1989 after the *Exxon Valdez* oil spill. In:

*Proceedings of the* Exxon Valdez *oil spill symposium*. S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright (eds.) Bethesda: American Fisheries Society pp. 463-486.

Norcross, B.L., M. Frandsen, J.E. Hose, and E.D. Brown. (1996) Distribution, abundance, morphological condition, and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the *Exxon Valdez* oil spill. *Can. J. Fish. Aquat. Sci.* **53**: 2376-2393.

Rice, S.D. (1999) Lessons learned from the long-term toxicity of oil to fish: Intersection of chance, oil, biology, toxicology, and science. 10th Anniversary *Exxon Valdez* Oil Spill Symposium, Anchorage, AK, March 1999.

Stokesbury, K.D.E. (1999) A reexamination of events influencing the 1993 Pacific herring (*Clupea pallasi*) population crash in Prince William Sound, Alaska. 10th Anniversary *Exxon Valdez* Oil Spill Symposium, Anchorage, AK, March 1999.

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Biographical Sketch of
**BRENDA L. NORCROSS**
SS# 355-42-8879

**Education:**

A.B., Biology, MacMurray College, Jacksonville, Illinois, 1971

M.S., Biology, St. Louis University, St. Louis, Missouri, 1976

Ph.D., Marine Science, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1983

**Experience:**

Associate Professor, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 1996-present

Assistant Professor, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 1989-1996

Assistant Professor, Division of Biological Oceanography and Fisheries Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1984-1988

**Field Experience:**

One fisheries vessel, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, underwater camera (Prince William Sound, 7 days), 1998.

One - five fisheries vessels, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, underwater camera, aerial surveys (Prince William Sound, 34 days), 1997.

Five fisheries vessels, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, aerial surveys (Prince William Sound, 60 days), 1996.

Six fisheries vessels, Principal Investigator, Pelagic fish, hydroacoustics, oceanography, aerial surveys (Prince William Sound, 22 days), 1995.

**Selected Publications:**

Foy, R.J. and B.L. Norcross. 1999. Spatial and temporal differences in the diet of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Can. J. Zoolog.* In press.

Moles, A. and B.L. Norcross. 1998. Effects of oil-laden sediments on growth and health of juvenile flatfishes. *Can. J. Fish. Aquat. Sci.* 55:605-610.

Norcross, B.L., J.E. Hose, M. Frandsen and E. Brown. 1996. Distribution, abundance, morphological condition and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the *Exxon Valdez* oil spill. *Can. J. Fish. Aquat. Sci.* 53:2376-2387.

Brown, E.D., B.L. Norcross and J.W. Short. 1996. Conditions affecting the distribution of oil from the *Exxon Valdez* spill and exposure of Pacific herring, *Clupea pallasi*, in Prince William Sound, Alaska. *Can. J. Fish. Aquat. Sci.* 53:2337-2342.

Norcross, B.L. and M. Frandsen. 1996. Distribution and abundance of larval fishes in Prince William Sound, Alaska during 1989 after the *Exxon Valdez* oil spill. *In* S.D. Rice, R.B. Spies, D.A. Wolfe and B.A. Wright (eds.). *Exxon Valdez* Oil Spill Symposium Proceedings. *Am. Fish. Soc. Symp.* 18:463-486.

Moles, A., S. Rice, and B.L. Norcross. 1994. Non-avoidance of hydrocarbon laden sediments by juvenile flatfishes. *Neth. J. Sea Res.* 32(3/4):361-367.

**2000 EXXON VALDEZ TRI E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Personnel | | $0.0 | | | | | | |
| Travel | | $0.0 | | | | | | |
| Contractual | | $44.7 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | | | | | | |
| Subtotal | $0.0 | $44.7 | | | Estimated FY 2001 | Estimated FY 2002 | | |
| General Administration | | $3.1 | | | | | | |
| Project Total | $0.0 | $47.8 | | | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.3 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

**FY00**

Prepared:

Project Number: 00373
Project Title: Effect of Exxon Valdez Oil Spill on Herring Spawning Locations and Use of Nursery Areas
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**2000 EXXON VALDEZ TRU_ _E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $27.6 |
| Travel | | $5.7 |
| Contractual | | $2.0 |
| Commodities | | $0.5 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $35.8 |
| Indirect | | $8.9 |
| Project Total | $0.0 | $44.7 |
| Full-time Equivalents (FTE) | | 0.3 |
| Other Resources | | |

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

Dollar amounts are shown in thousands of dollars.

Comments:

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

**FY00**

Prepared:

Project Number: 00373
Project Title: Effect of Exxon Valdez Oil Spill on Herring Spawning Locations and Use of Nursery Areas
Name: Brenda L. Norcross

FORM 4A
Non-Trustee
SUMMARY

**2000 EXXON VALDEZ TRI E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| | Name | Position Description | Budgeted | Costs | Overtime | FY 2000 |
| | Norcross, B. | Principal Investigator/Assoc. Prof. | 2.0 | 8.5 | | 17.0 |
| | Frandsen, M. | Technician | 2.0 | 5.3 | | 10.6 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | Subtotal | 4.0 | 13.8 | 0.0 | |
| | | | | | **Personnel Total** | $27.6 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| | Description | Price | Trips | Days | Per Diem | FY 2000 |
| | Fairbanks to Miami | 0.9 | 4 | 20 | 117.0 | 5.7 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $5.7 |

**FY00**

Prepared:

Project Number: 00373
Project Title: Effect of Exxon Valdez Oil Spill on Herring Spawning Locations and Use of Nursery Areas
Name: Brenda L. Norcross

FORM 4B
Personnel
& Travel
DETAIL

**2000 EXXON VALDEZ TRI E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Communications | 1.0 |
| Page charges/reprints | 1.0 |
| **Contractual Total** | $2.0 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Office supplies | 0.5 |
| **Commodities Total** | $0.5 |

**FY00**

Prepared:

Project Number: 00373
Project Title: Effect of *Exxon Valdez* Oil Spill on Herring Spawning Locations and Use of Nursery Areas
Name: Brenda L. Norcross

FORM 4B
Contractual & Commodities
DETAIL

**2000 EXXON VALDEZ TRI E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | 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 |
| 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 |
| | |

**FY00**

Prepared:

Project Number: 00373
Project Title: Effect of Exxon Valdez Oil Spill on Herring Spawning Locations and Use of Nursery Areas
Name: Brenda L. Norcross

FORM 4B
Equipment
DETAIL

# Regional analysis of juvenile herring in Prince William Sound

| | |
|---|---|
| Project Number: | 00374 |
| Restoration Category: | Research |
| Proposer: | University of Alaska Fairbanks |
| Lead Trustee Agency: | ADF&G |
| Cooperating Agencies: | none |
| Alaska Sea Life Center: | no |
| Duration: | 1st year, 1-year project |
| Cost FY 00: | **$37,415** |
| Cost FY 01: | 0 |
| Cost FY 02: | 0 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | Pacific herring |



## ABSTRACT

This study proposes to further analyze larval and herring distribution data collected within bays in Prince William Sound during the SEA project. Specifically, we propose to examine the small-scale distribution of herring in relation to physical characteristics within bays used as nursery areas. We expect this to result in an explanation of differences in factors that affect survival of juvenile herring among bays discovered during SEA investigations (\320-T). We will examine broader implications by comparing the results to those of Atlantic herring.

## INTRODUCTION

The SEA program studied the life history of herring, concentrating on the early life stages (\320-T), and presented the synthetic results of herring life history at the EVOS meeting (Norcross et al., 1999). From the SEA studies we learned that bays within PWS are nursery areas for herring and that what happens to herring juveniles within nursery bays is critical to their survival. Specifically, we discovered that the overall energy content of juvenile herring differs among bays, diet competition differs among bays, growth of juveniles differs among bays, and survival of juveniles differs among bays (Norcross et al., in prep.). While we have analyzed results of herring around the sound and within nursery areas (Foy and Norcross, in press; Norcross et al., in prep; Stokesbury et al., In Press; In Review a & b), there are several important facets of herring life history knowledge still to be gained from this data set.

Analysis of distribution of herring within the bays themselves in relation to physical parameters has not yet been analyzed. Physical variables within the bays have been examined (Gay and Vaughan, in prep.) and initially indicate explanations for the distribution and retention patterns of herring within bays. Examination of the four bays (Eaglek, Simpson, Whale and Zaikof) that were the focus of the SEA herring studies reveals that the physical characteristics differ among them. Thus, a more in-depth analysis of the specific hydrography associated with each of the bays may explain the distribution of the herring larvae and juveniles within the bays. Furthermore, the distribution of the herring juveniles within the bays in concert with the physical characteristics may help explain the differences in factors that affect survival of juvenile herring among bays that SEA found (Norcross et al., in prep.). Additionally, results of drifters released within PWS (Vaughan et al., 1998) indicate that there may be movement among bays, perhaps on a regional basis. Closer examination of this aspect is needed to evaluate the successful recruitment of herring juveniles.

## NEED FOR PROJECT

### A. Statement of Problem

Pacific herring are listed as a recovering resource. Much research has already been conducted on herring that has provided insight as to the causes of decline of the species and the conditions necessary for it to recover. While we cannot directly restore the herring population size, we can investigate specific impediments that prevent this recovery. Knowledge of what factors influence the differential survival of juvenile herring among nursery areas is necessary to understanding recovery of the species.

### B. Rationale/Link to Restoration

The proposed project builds upon results from two components of the SEA project, juvenile herring (\320-T) and physical oceanography (\320-M). We will use the physical oceanographic data and larval and juvenile herring distribution data collected during SEA to examine the small-scale distribution of herring within bays. We will use this small-scale examination of herring to understand the causes of the differential survival among bays. SEA identified the time juveniles spend in nursery areas as a particularly vulnerable period in the life history of herring because that is when they have to eat enough to acquire sufficient energy to survive throughout the winter without feeding (Foy and Paul, in press). Understanding more about the factors influencing this ability to survive in relation to other factors that potentially impact herring recruitment success (Norcross et al., in prep.) will improve the understanding of herring recruitment success and will be valuable to managers of herring.

### B. Location

The proposed analysis will be for PWS only.

## COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

The background knowledge on which this proposal is based was collected and analyzed as part of the SEA project, including herring (\320-T), physical oceanography (\320-M) and local and traditional ecological knowledge (\320-T Supplement). During those projects, local commercial fishing vessels were hired, local Cordovans were employed, and purchases were made locally in Cordova. The results of this project will be made available through public media to residents of PWS. We will communicate our results directly to local herring fisheries managers.

## PROJECT DESIGN

### A. Objectives

The research objectives of this project are:

1. To analyze the within-bay distribution of larval and juvenile herring.

2. To compare the within-bay distribution of larval and juvenile herring to the within-bay physical characteristics.

3. To compare the within-bay distribution of herring to the factors which affect survival, i.e., food availability and energy content.

4. To compare patterns of Pacific herring within nursery areas to those of Atlantic herring within nursery areas.

## B. Methods

We will analyze larval and juvenile herring distribution data (\320-T) and physical data (\320- M) previously collected by SEA within bays in PWS to determine the effects of small-scale distribution.

We hypothesize that hydrographic characteristics affect the distribution of larval and juvenile herring within the bays of PWS. We further hypothesize that the particular distribution pattern of herring and the causative hydrography within a bay explains the among-bay differences in the ability of herring to feed and acquire energy necessary to survive through winter. These among-bay differences were one of the principal findings of the SEA herring synthesis (Norcross et al., in prep.).

We will analyze the distribution of larval and juvenile herring within bays for all available collection periods: May, June, July August, and October 1996, and March, May, July, August, and October 1997, and March 1998. This will use both the hydroacoustic and the net capture data and will require compilation of data in a different format than previously calculated. Comparisons of herring will be of relative, not absolute, abundance. Spatial gradients of distribution of herring within bays will be plots analogous to the spatial gradients plotted of temperature and salinity within bays (Gay and Vaughan, in prep.) Plots of distribution of larval and juvenile herring within bays will be compared among seasons within single bays. Similar comparisons will be made among bays. These plots will then be compared with the plots of the physical characteristics (Gay and Vaughan, in prep.).

This analysis will then be expanded beyond the within-bay scale to include data from drifters released in PWS (Vaughan et al., 1998; in prep.). These data indicate that there is movement among adjacent bays within the sound. Therefore, we will investigate the possibilities for herring to move out of one bay and into another based on the small-scale hydrographic conditions. The results of this analysis will influence our interpretation of the effect of physical factors on survival of juvenile herring.

Brenda Norcross and Michele Frandsen will conduct compilation and analysis of the herring data in the Fisheries Oceanography Lab at UAF in Fairbanks. Shelton Gay and Shari Vaughan of Prince William Sound Science Center, Cordova, already have analyzed most of the physical data (Gay and Vaughan, in prep.). These scientists will cooperatively analyze the interactions of the fish and physical data. Because of the close collaboration necessary among investigators, funds for two trips between Fairbanks and Cordova are requested in the budget.

Norcross will then compare the results of the distribution of the larval and juvenile herring within bays, and in relation to the physical characteristics, with results of the SEA synthesis (Norcross et al., in prep.) and specific SEA studies regarding feeding and

energetics (Foy and Paul, In Press). Norcross also will compare the results with similar published results of Atlantic herring retention (Sinclair, 1988) to discern the broader implications of the processes identified in the proposed study.

No alternative methodologies are available as this study proposes to examine the only data set of this kind in existence.

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

The University of Alaska Fairbanks is the only entity requesting funds in this proposal. Collaboration with Dr. Shari Vaughan and Shelton Gay at Prince William Sound Science Center is critical to completion of this project. Results will be shared with herring biologists at ADF&G in Cordova.

## SCHEDULE

### A. Measurable Project Tasks for FY ) (October 1, 1999 – September 30, 2000)

| | |
|---|---|
| November 30: | Compilation of within-bay herring data |
| January 18-28 (3 of these days): | Attend Annual Restoration Workshop |
| January 31: | Production of plots of herring |
| February 1 –March 31: | Comparison of herring and physical data |
| April 1 – May 30: | Comparison with factors affecting survival |
| June 1 – July 31: | Comparison with Atlantic herring |
| August 1 – September 30: | Write manuscript for peer-reviewed journal |

### B. Project Milestones and Endpoints

| | |
|---|---|
| January 31: | Objective 1: Distribution of herring |
| February 1 –March 31: | Objective 2: Compare herring and physical data |
| April 1 – May 30: | Objective 3: Compare to factors affecting survival |
| June 1 – July 31: | Objective 4: Compare to Atlantic herring |

### C. Completion Date

30 September 2000

## PUBLICATIONS AND REPORTS

Final Report (April 15, 2001)

Within-bay distribution and retention of juvenile herring in Prince William Sound. B.L. Norcross, S.L. Vaughan, S.M. Gay and M. Frandsen. *Estuarine, Coastal and Shelf Science*.

## PROFESSIONAL CONFERENCES

The Principal Investigator will present the results of the this research at the 18th Wakefield Symposium: Herring 2000, an International Symposium on Expectations for a New Millennium, Anchorage, AK, February 23-26, 2000. A presentation on small-scale distribution of herring within bays will be given.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will address questions raised from previous and ongoing Restoration projects about effects of the physical environment on herring within bays. We will coordinate this research with that proposed by Dr. Shari Vaughan to make the comparisons between the herring and physical data and write the proposed manuscript. We will also incorporate the results from a study proposed by Dr. A.J. Paul and R.J. Foy (451) entitled "The influence of exogenous zooplankton assemblages on juvenile herring nursery areas."

## PROPOSED PRINCIPAL INVESTIGATOR

Brenda L Norcross
University of Alaska Fairbanks
Institute of Marine Science
School of Fisheries and Ocean Sciences
Fairbanks, AK 99775-7220
Phone: 907-474-7990
Fax: 907-474-1943
E-mail: norcross@ims.alaska.edu

## PRINCIPAL INVESTIGATOR

Dr. Brenda L. Norcross has been an EVOS investigator on the SEA herring project (\320T) since 1995. She has been the PI responsible for the collection of the larval and juvenile data to be examined in this study. She is thus qualified to perform all analysis required for this project.

## OTHER KEY PERSONNEL

Dr. Shari Vaughan and Shelton Gay have submitted a separate proposal to perform the duties required as co-authors on the proposed manuscript. They have been studying the physical oceanography in PWS since 1994 (\320-M) and are uniquely qualified to cooperate in the comparison of distribution of herring to the hydrography within bays.

## LITERATURE CITED


Foy, R.J. and B.L. Norcross (In press) Spatial and temporal differences in the diet of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Can. J. Zool.*

Foy, R.J. and A.J. Paul. (In Press) Winter feeding and changes in somatic energy content for age 0 Pacific herring in Prince William Sound, Alaska. *Trans. Amer. Fish. Soc.*

Gay, S.M. and S.L. Vaughan (In preparation) Seasonal hydrography and tidal currents of bays and fjords in , Alaska used as nursery habitats by juvenile Pacific herring (*Clupea pallasi*). *Fish. Oceanog.*

Norcross, B.L., E.D. Brown, R.J. Foy, M. Frandsen, S. Gay, M. Jin, T.C. Kline, J. Kirsch, D.M. Mason, C.N.K. Mooers, E.V. Patrick, A.J. Paul, K.D.E. Stokesbury, S.J. Thornton, S.L. Vaughan, and J. Wang. Life History of Herring in Prince William Sound, Alaska. 10th Anniversary *Exxon Valdez* Oil Spill Symposium, Anchorage, AK, March 1999.

Norcross, B.L., E.D. Brown, R.J. Foy, M. Frandsen, S. Gay, M. Jin, T.C. Kline, J. Kirsch, D.M. Mason, C.N.K. Mooers, E.V. Patrick, A.J. Paul, K.D.E. Stokesbury, S.J. Thornton, S.L. Vaughan, and J. Wang. (In Preparation) Early Life History of Herring in PWS. *Fish. Oceanogr.*

Sinclair, M. (1988) Marine Populations: An Essay on Population Regulation and Speciation. Washington Sea Grant Program, University of Washington Press, Seattle, WA. 252 pp.

Stokesbury, K.D.E., R.J. Foy and B.L. Norcross. (In Press) Spatial and temporal variability in juvenile Pacific herring (*Clupea pallasi*) growth in Prince William Sound, Alaska. *Environ. Biol. Fish.*

Stokesbury, K.D.E., J. Kirsch, E.D. Brown, G.L. Thomas and B.L. Norcross. In Review a. Seasonal variability in Pacific herring (*Clupea pallasi*) and walleye pollock (*Theragra chalcogramma*) spatial distributions in Prince William Sound, Alaska. *Mar. Ecol. Prog. Ser.*

Stokesbury K.D.E., J. Kirsch, and B.L. Norcross In Review b. Relative mortality estimates and spatial distribution of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Mar. Ecol. Prog. Ser.*

Vaughan, S.L., S.M. Gay, and L.B. Tuttle (1998) Oceanography of Prince William Sound bays and fjords. Restoration Project 98297 Annual Report.

Vaughan, S.L., C.N.K. Mooers, J. Wang, S.M. Gay, and L.B. Tuttle (In Preparation) Physical oceanography synthesis paper. *Fish. Oceanog.*

Biographical Sketch of
**BRENDA L. NORCROSS**
SS# 355-42-8879

**Education:**

A.B., Biology, MacMurray College, Jacksonville, Illinois, 1971

M.S., Biology, St. Louis University, St. Louis, Missouri, 1976

Ph.D., Marine Science, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1983

**Experience:**

Associate Professor, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 1996-present

Assistant Professor, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 1989-1996

Assistant Professor, Division of Biological Oceanography and Fisheries Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1984-1988

**Field Experience:**

One fisheries vessel, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, underwater camera (Prince William Sound, 7 days), 1998.

One - five fisheries vessels, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, underwater camera, aerial surveys (Prince William Sound, 34 days), 1997.

Five fisheries vessels, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, aerial surveys (Prince William Sound, 60 days), 1996.

Six fisheries vessels, Principal Investigator, Pelagic fish, hydroacoustics, oceanography, aerial surveys (Prince William Sound, 22 days), 1995.

**Selected Publications:**

Foy, R.J. and B.L. Norcross. 1999. Spatial and temporal differences in the diet of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Can. J. Zoolog.* In press.

Norcross, B.L. and F.J. Mueter. 1999. The use of an ROV in the study of juvenile flatfishes. *Fish. Res.* 39:241-251.

Moles, A. and B.L. Norcross. 1998. Effects of oil-laden sediments on growth and health of juvenile flatfishes. *Can. J. Fish. Aquat. Sci.* 55:605-610.

Norcross, B.L., J.E. Hose, M. Frandsen and E. Brown. 1996. Distribution, abundance, morphological condition and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the *Exxon Valdez* oil spill. *Can. J. Fish. Aquat. Sci.* 53:2376-2387.

Brown, E.D., B.L. Norcross and J.W. Short. 1996. Conditions affecting the distribution of oil from the *Exxon Valdez* spill and exposure of Pacific herring, *Clupea pallasi*, in Prince William Sound, Alaska. *Can. J. Fish. Aquat. Sci.* 53:2337-2342.

Norcross, B.L. and M. Frandsen. 1996. Distribution and abundance of larval fishes in Prince William Sound, Alaska during 1989 after the *Exxon Valdez* oil spill. *In* S.D. Rice, R.B. Spies, D.A. Wolfe and B.A. Wright (eds.). *Exxon Valdez* Oil Spill Symposium Proceedings. *Am. Fish. Soc. Symp.* 18:463-486.

**Brenda L. Norcross -- current and pending research**

EVOS Trustees – This proposal, Pending, 1999-2000,$37,415 (PI time = 1 mos, 9/30/00)
EVOS Trustees – Effect of Exxon Valdez oil spill on herring spawning locations and use of nursery areas, Pending, 1999-2000, $44,680 (PI time = 2 mos, 9/30/00)
EVOS Trustees – Effect of herring egg distribution and ecology on year-class strength and adult distribution, Pending, 1999-2000, $44,700, Co-PI (PI time = .5 mos, 9/30/00)
EVOS Trustees – Effects of forage fish school density and species composition on foraging patterns of sea birds: An EVOS synthesis product, Pending, 1999-2000, $55,755, Co-PI (PI time = 0 mos, 9/30/00)
EVOS Trustees – Ecological factors effecting distribution and abundance of forage fish in Prince William Sound, AK: An APEX synthesis product, Pending, 1999-2000, $100,941, Co-PI (PI time = 0 mos, 9/30/00)
Alaska Sea Grant – Halibut diets as indicators of prey available to apex predators, Pending, 2000-2002, $222,168 (PI time = 3 mos, end-date = 1/31/02)
EVOS Trustees - Juvenile herring distribution and habitats, 1998-99, $150,000 (PI time = 3 mos. ; end date = 9/30/99)
EVOS Trustees - Effects of herring egg distribution and ecology on year-class strength, and adult distribution 1998-99, $76,500, Co-PI. (PI time = 0 mos. ; end date = 9/30/99)
EVOS Trustees - Aerial survey support for the APEX project, 1998-99, $54,400, Co-PI. (PI time = 0 mos. ; end date = 9/30/99)
EVOS Trustees - Documenting forage fish natural history through local and traditional ecological knowledge, 1998-99, $25,100, Co-PI. (PI time = 0 mos. ; end date = 9/30/99)
Alaska Fisheries Development Foundation - Expert system reduction in flounder bycatch in Gulf of Alaska, 1997-99, $64,752, Co-PI. (PI time = 1.75 mos. ; end date = 5/31/99)
Coastal Marine Institute - The relationship of diet to habitat preferences of juvenile flatfishes in Kachemak Bay, Alaska, Phase 1. 1997-98, $46,212. (PI time = 1.5 mos. ; end date = 6/30/99)
North Pacific Universities Marine Mammal Research Consortium (UBC) - Forage fish abundance and distribution at Forrester Island, Alaska, 1997-99, $172,023. (PI time = 3 mos. ; end date = 12/31/99)
University of Alaska Natural Resources Fund - Food for Steller sea lions, 1997-98, $20,000. (PI time = 0 mos. ; end date = 12/31/99)
University of Alaska Natural Resources Fund - Larval fishes in the North Pacific. 1999-2000, $15,973. (PI time = 0 mos. ; end date = 3/31/00)

**2000 EXXON VALDEZ TRU  E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $37.5 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $37.5 |
| General Administration | | $2.6 |
| Project Total | $0.0 | $40.1 |
| Full-time Equivalents (FTE) | | 0.3 |
| Other Resources | | |

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

Dollar amounts are shown in thousands of dollars.

Comments:

**FY00**

Prepared:

Project Number: 00374
Project Title: Regional Analysis of Juvenile Herring in Prince William Sound
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

## 2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $24.3 |
| Travel | | $3.2 |
| Contractual | | $2.0 |
| Commodities | | $0.5 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $30.0 |
| Indirect | | $7.5 |
| Project Total | $0.0 | $37.5 |
| Full-time Equivalents (FTE) | | 0.3 |
| Other Resources | | |

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

Dollar amounts are shown in thousands of dollars.

Comments:

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

**FY00**

Prepared:

Project Number: 00374
Project Title: Regional Analysis of Juvenile Herring in Prince William Sound
Name: Brenda L. Norcross

FORM 4A
Non-Trustee
SUMMARY

## 2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| | Name | Position Description | Budgeted | Costs | Overtime | FY 2000 |
| | Norcross, B. | Principal Investigator/Assoc. Prof. | 1.0 | 8.5 | | 8.5 |
| | Frandsen, M. | Technician | 3.0 | 5.3 | | 15.8 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | Subtotal | 4.0 | 13.8 | 0.0 | |
| | | | | | **Personnel Total** | $24.3 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| | Description | Price | Trips | Days | Per Diem | FY 2000 |
| | Fairbanks to Cordova | 300.0 | 2 | 7 | 120.0 | 1.5 |
| | Fairbanks to Anchorage (Herring meeting) | 300.0 | 1 | 5 | 140.0 | 1.0 |
| | Fairbanks to Anchorage (EVOS meeting) | 300.0 | 1 | 3 | 140.0 | 0.7 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $3.2 |

**FY00**

Prepared:

Project Number: 00374
Project Title: Regional Analysis of Juvenile Herring in Prince William Sound
Name: Brenda L. Norcross

FORM 4B
Personnel
& Travel
DETAIL

**2000 EXXON VALDEZ TRL E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Communications | 1.0 |
| Page charges/reprints | 1.0 |
| **Contractual Total** | $2.0 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Office supplies | 0.5 |
| **Commodities Total** | $0.5 |

**FY00**

Prepared:

Project Number: 00374
Project Title: Regional Analysis of Juvenile Herring in Prince William Sound
Name: Brenda L. Norcross

FORM 4B
Contractual & Commodities DETAIL

## 2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

| **New Equipment Purchases:** | Number of Units | Unit Price | Proposed FY 2000 |
|---|---|---|---|
| Description | | | |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

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

**FY00**

Prepared:

Project Number: 00374
Project Title: Regional Analysis of Juvenile Herring in Prince William Sound
Name: Brenda L. Norcross

FORM 4B
Equipment
DETAIL

# Effect of Herring Egg Distribution and Ecology on Year-Class Strength and Adult Distribution

| | |
|---|---|
| Project Number: | 00375 |
| Restoration Category: | Research |
| Proposer: | University of Alaska Fairbanks |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | none |
| Alaska SeaLife Center: | no |
| Duration: | 2nd year, 2-year project |
| Cost FY 00: | $44,700 +ADFG $3,129 = $47,8297 |
| Cost FY 01: | 0 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | Pacific herring |



## ABSTRACT

The objective of this project is to examine the effect of Pacific herring egg distribution and abundance as well as oceanographic processes on year-class strength and adult distribution. Existing data is used in the analysis. The findings of this study will aid in understanding stock structure and population dynamics of herring in Prince William Sound. This information will facilitate area-specific targeting of catches and provide maximum conservation of the overall population. The methodology is applicable to other species and areas. This project will provide scientific documentation of unpublished fishery data. The companion proposal to this is entitled "Distribution and Ecology of Forage Fish and Effects on Herring Year-Class Strength."

## INTRODUCTION

The overall objective of this project is to refine our understanding of Pacific herring (*Clupea pallasi*) population structure and trends in Prince William Sound (PWS) by examining current and historic data on fish distribution within an ecological context. The components of this project include:

1. Defining temporal trends of early life history (eggs) distribution.

2. Describing the relationship between that distribution and the oceanography of PWS.

3. Analyzing the impact of that distribution in the context of the oceanographic conditions on population structure and abundance 3–4 years later.

The main idea to be addressed is that both egg density and distribution affect the resulting adult population since processes affecting the early life history stages (incubation, larval drift, and juvenile rearing in nearshore bays) vary on spatial regional scales within PWS. An oceanographic region is defined by an area that has relatively homogenous conditions within a given season. Although the size and boundaries of oceanographic regions within PWS are likely to vary between seasons, we are focusing on late spring and summer since that is when larval drift and recruitment to nearshore nursery bays are most affected. We feel that processes occurring during the larval and early juvenile stages are therefore deterministic in the resulting year-class strength as adults. In addition, if, via our analysis, we determine that winter conditions may "set the stage" for the following spring and summer conditions, we may add a winter variable.

Originally we planned to extend the analysis if significant results were produced and include biological indices such as size-at-age, and for recent years, energetic content, isotopic values, fatty acid signatures, growth rates, and possibly feeding rates. It has now been determined that the availability of biological indices for broadscale analysis is very limited. The most useful indice is size-at-age (of newly recruited adults). The remaining indices mentioned above, exist only for 1995-1998 and can be derived from existing or recently submitted publications. Therefore, we propose to combine these results in the proposed publication and analysis, to be completed in the close-out year of the project. This publication would examine the effects of ocean condition and egg distribution of adult population distribution, abundance and size-at-age. The biological indices from the last four years would be used to provide further evidence of the hypothesized population structure derived from the analysis. Fatty acids were collected from a large sample of herring from PWS (Iverson et al. 1998) and represent one of the biological indices that could be used to test our stock structure hypothesis.

Since 1995, our knowledge and understanding of temporal and spatial variability in the oceanography as well as herring ecology in PWS have improved considerably because of the work by the Sound Ecosystem Assessment (SEA) project (Cooney 1997). Vaughan et al. (in prep.) have shown that stratification of the surface waters begins in April some years, later in others. In addition, the strength and duration of that stratification varies from year to year and spatially within PWS. Surface stratification forms first and is strongest in the northern central Sound. The presence and strength of an anticyclonic baroclinic eddy in the central Sound varies

from year to year as well. Vaughan et al. (in prep.) summarized conditions for a "good" year (in terms of productivity) potentially as a cold harsh winter followed by a warm, calm spring and a semi-stormy summer creating the following conditions: 1) stratification formation, 2) a second fall bloom, and 3) minimized flushing. Zooplankton production peaks with maximum stratification but the intensity and duration of the bloom depend on mixing events due to storms and tides throughout the summer (Cooney et al. in prep.). For the three SEA years, it appears that the highest secondary production occurred in 1996 (Vaughan et al. in prep.) apparently due to the occurrence of a set of "priming" conditions similar to those listed above. During two of the SEA years, 1995 and 1997, more zooplankton appeared in the northern sound in May than other areas, but by June, the southern region had higher productivity. In 1996, zooplankon were abundant sound wide (Vaughan et al. in prep.).

Further evidence for regionalization in PWS comes from SEA data collected at juvenile herring nursery sites. Age-0 herring diets collected from distant regions of PWS varied considerably within a given season both in species composition and stomach fullness indices (Foy and Norcross, in prep.). The length frequency of herring of the same age from these same distant sites also varied (Stokesbury et al. 1997) indicating variations in growth and possibly hatch cohort. Kline (1998) found that isotopic signatures of zooplankton within PWS varied on a regional and seasonal scale and appeared linked to physical processes affecting transport of Gulf of Alaska (GOA) carbon into the Sound.

The main working hypothesis for this project is:

> Adult Pacific herring year-class strength and distribution is dependent on the initial distribution and density of herring embryos, modulated by ocean conditions during the first two years of life.

A corollary that has been developed this year based on SEA study results is:

> The herring in Prince William Sound can be divided into three main sub-populations defined by spawning region and forced by distinctive regional oceanographic processes: 1) the eastern group 2) the central group (currently the largest of the three) and 3) the northern group.

An annual progress report for this project will be available in June of this year.

## NEED FOR THE PROJECT

### A. Statement of Problem

Pacific herring are a key species in the marine ecosystem of Prince William Sound. The health of the apex predator community may depend on the magnitude of herring recruitment and the condition of individual fish, since herring are the key forage fish in the sound (Lew Haldorson, UAF, personal communication). The decline of the PWS herring population (Brown et al. 1996a and 1996b) has had serious and significant negative impacts on commercial fisheries, subsistence food-harvest patterns, and distribution of wildlife in areas now devoid of herring spawning and

feeding. The effects of these impacts on oil-injured predators of herring are only beginning to be understood by other EVOS-funded researchers. Nine years after the spill, Pacific herring are still listed by the EVOS Trustee Council as "injured and not recovering." Direct restoration of this species is not practical; however, understanding and monitoring its recovery is important in order to improve stock assessment for management of commercial fisheries. Recovery can only take place via successful recruitment of juvenile herring to the adult population in PWS.

### B. Rationale/Link to Restoration

The research completed under this project combined with historic data from ADFG and current information from the SEA project will help us refine models describing processes controlling and regulating herring recruitment. This information will help us to better understand the dynamics of the recovery of this species.

### C. Location

The data for the work included in the proposal are limited to Prince William Sound.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

We will utilize the results of the TEK project 98320-T supplement entitled, "Documenting Forage Fish Natural History through Local and Traditional Ecological Knowledge." Specifically, the findings of this project will be compared with observations from resource users over the past 50 years. The TEK project documents observations of individuals, which coincide, with observations herring researchers have recorded in recent years. The Principal Investigator, Evelyn Brown, is also the Principal Investigator for the TEK project and will assist with closeout and publication preparation. The findings of this study will be shared with interested participants in the herring TEK project.

## PROJECT DESIGN

### A. Objectives

The research questions followed by the specific objectives for FY99 were:

How does herring egg density and year-class strength 3–4 years later vary geographically over time?

1. Determine temporal and spatial variability of herring spawn and year-class strength.

2. Identify natural groupings of the data and areas with greater variability.

   Is there coherence in the trends of the two life stages?

3. Determine the correlation between the magnitude of spawn and the year-class strength.

How are egg and adult distributions compartmentalized oceanographically in PWS?

4. Define oceanographic regions and their associated hydrography within PWS.

   How do oceanographic trends within the regions modify the coherence among the trends of herring egg and adult distribution and abundance?

5. Determine the relationships and interactions among the regional magnitude of spawn, oceanographic conditions, and year-class strength.

6. Examine areas of greater variability or similarity in the biological indices by comparing the oceanography.

The findings related to objectives 1-4 will be reported in June, 1999.

*FY 00*
Is biological evidence consistent with the ecological evidence for regionalization or the formation of sub-populations of herring in PWS?

1. Compile biological indices (energetics, growth, diet, etc.) stratified by region for juvenile and adult herring in PWS.

2. Determine how biological indices interact with oceanographic variables and affect year-class strength.

Our main task in FY 00 will be the completion of the publication including the analysis of all of the above listed tasks.

## B. Methods

*Construction of Variables*
One of the main tasks for this project is the formation of sound wide and regional variables from data compilations from a variety of sources. The variables to be produced for the analysis can be categorized as response or predictor:

| Variable | Source |
|---|---|
| **Response** | |
| Age-3 & 4 (adult) herring distribution and abundance by year | ADFG |
| Adult herring size-at-age | ADFG |
| **Predictor** | |
| Herring egg distribution and density | ADFG |
| Oceanographic variables | SEA Program Data |
| (further categorized as "sound wide" or regional) | (reformatted by PWSSC) |

*Sound wide*
Summer inflow/outflow of PWS waters at Hinchinbrook Entrance

Wind velocity (direction and strength)
Variability in wind velocity over the period of interest
Bakun Upwelling Index (avail. through 1948; but possibly less meaningful than wind alone)
Precipitation and variability of precip.
Hydrological Data (freshwater input via terrain)
Winter "condition" indice (average temperature and snowfall)
Zooplankton peak biomass (at the salmon hatcheries) Cooney/Coyle UAF IMS
Zooplankton bloom duration Cooney/Coyle UAF IMS

*Regional* SEA data reformatted by PWSSC
Temperature (to 20m)
Salinity (to 20m)
T/S anomalies over the period
T/S time plots (variability of time)*
Initiation date of summer bloom**
Initiation and length of stratification

We will also cite data from various researchers and recent studies in PWS to test the regional hypotheses found. For example, we may see if differences in herring energetics (Paul et al. 1998), diet (Foy and Norcross, in press), or fatty acid composition (Iverson et al. 1998) that may be partially explained by the regions we propose.

*Establishing Regional Scale for Oceanographic Variables*
From 1993 on, satellite images are available in a variety of formats, each providing different information about PWS and the adjacent Gulf of Alaska. Advanced Very High Radiation Radiometer (AVHRR) images will indicate eddies and currents. Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) images provide ocean color, and Synthetic Aperture Radar (SAR) images show ocean front structure under cloud cover. These three images together, along with a subset of hydrographic data within regions of interest, may indicate structure that affects partitioning of the herring population (during larval drift and rearing in nursery areas). Kevin Engle, a satellite imagery specialist at the UAF Geophysical Institute, will compile and summarize these images for the project. For years prior to 1993, oceanographers at the Prince William Sound Science Center have compiled a set of historic hydrographic and meteorological data for the region. By subsampling this data set within the same regions subsampled for the recent data series, hydrographic data should be comparable between the two time periods (post- and pre-1993). Therefore, we should be able to look, retrospectively, at the same conditions that may act in partitioning. We will most likely do this for a subset of the 20 years since there are holes in the historic data set. However, the ultimate definition of oceanographic regions that have biological implications will depend on analysis of the biological (herring) variables.

*Statistical Analysis of Herring Data*
A variety of graphic and statistical methods will be applied in this analysis. The distribution data (eggs and adult population) vary in time and space. The simplest way to visualize this variability is to draw a circle that encompasses all historic spawning and adult spawner staging areas, stretch that circle out in a line, and plot the abundance information on the line. In this way, segments of the line represent regions. Although this linear scale is arbitrary (not a true continuous variable

like time), statistical analyses can be performed between segments of the line which represent independent events (individual spawning areas). By looking at each year individually and at all years pooled graphically, we will use the data to identify clusters (i.e., regions). The initial graphical examination of the data will indicate trends that will be obvious and will guide the analysis itself.

The first step, once extended graphical analysis is complete, will be to run a cross-correlation (time-series method; Rothschild et al. 1996) between the predictor variable of spawn abundance versus the response variable year-class strength within each region. Coherence between the trends may be highly variable, but that information will tell us which regions vary more and will guide the link to the environment. In performing the time-series, instances of auto-correlation between areas and years may become evident. The models selected from analysis should be able to deal with this problem.

*Linking Predictor and Response Variables*

Checking our data for violation of statistical model assumptions will be an important step. We have chosen to use general additive models (GAM), categorized as non-parametric regression, since that approach does not require linearity or normality. However, uniform variance is an assumption. Therefore, we will examine the residuals of the variables among regions. If there are serious departures from uniform variance, transformations may have to be performed. If the relationships between the predictor and response variables are largely linear (or can be linearized via transformations), we can perform a simple analysis of variance (ANOVA) and multiple regression to identify the important parameters. However, it is anticipated that many of the relationships will be non-linear and that oceanographic variables will be non-normal. The choice for a GAM is therefore clear.

Once we have a thorough understanding of the data and variability, we can proceed with the GAM analysis. This step involves compartmentalizing all the variables, biological and physical, within the regions identified. The general model takes the form:

$$\ln(R) = \alpha + \sum_{j=1}^{p} f(E_j) + g(S) + \varepsilon$$

where $R$ is the year-class strength, $\alpha$ is an intercept parameter, $p$ is the number of environmental predictor variables, $f(E_j)$ a function of the environment predictor variables (continuous or class; linear or non-linear forms), and $g(S)$ is the function of egg abundance ("mile-days" of spawn) (modified from Hastie and Tibshirani 1990; Jacobson and MacCall 1995; Swartzman et al. 1992). Multiple iterations of this model will be run with some variables falling out and others emphasized.

It is probable that there will be regions of high variability (i.e., major but inconsistent spawning areas). It could be that those areas are at the edges of oceanographic regions and that the variability is due to "phase" shifts in the environment. We will explore trends in those regions more thoroughly by adding class variables to the analysis to account for significant interannual shifts in conditions. There may also be indications for pooling of regions with similar trends in population dynamics and ocean conditions.

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

The University of Alaska Fairbanks is the main entity included in this proposal. We will work with co-authors from the Prince William Sound Science Center during the completion of the manuscript. We will share all findings with the Alaska Department of Fish and Game in the case that this information may be useful in refining management practice.

## SCHEDULE

### A. Measurable Project Tasks for FY 00 (October 1, 1999 – September 30, 2000)

November 30: Compile the list of biological indices to be compared to the model output; determine if any coherence and define apparent relationships to physical variables

February 28: Revise publication (back from submission); Produce final report

### B. Project Milestones and Endpoints

*FY 00*

October 27–30: Attend Lowell Wakefield Symposium; present analysis

November 30: Compile and compare the biological indices stratified by the regions defined in FY99 (Objective 1 & 2)

February 28: Publication revised and resubmitted; final report

### C. Completion Date

February 28, 2000

## PUBLICATIONS AND REPORTS

The final report for this project will be in the form of publication reprints. Documentation of all the findings will be available to EVOS as attached appendices. This report will also be included as a Ph.D. dissertation chapter by Evelyn Brown. The draft title for the publication is:

> Effects of trends in herring egg distribution and local oceanography on Pacific Herring year-class strength, distribution and size-at-age. E.D. Brown, S. Vaughn, K. Engle, and B.L. Norcross.

For the second year of the project, we will either expand the above publication to include the comparison of biological indices or we will produce a note entitled:

Evidence of ecologically induced population structure and spatial segregation on Pacific herring in Prince William Sound, Alaska. E.D. Brown and these potential co-authors: B.L. Norcross, K.D.E. Stokesbury, R.J. Foy, A.J. Paul, S. J. Iverson, F. Funk, J. Wilcock, T. Kline.

## PROFESSIONAL CONFERENCES

During FY 00 we will attend the Lowell Wakefield Symposium entitled, Spatial Processes and Management of Fish Populations, October 27–30, 1999.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project represents a synthesis of historic data and current information resulting from EVOS restoration research. Data from the SEA project (98320) and from ADFG are pivotal in the research. This will also be one of the first attempts to relate satellite data to effects on marine fishes. The results from this study also dovetail with work on herring recruitment being completed by Terry Quinn (UAF Juneau Center) and Erik Williams. The scale of the analyses differ substantially.

## PRINCIPAL INVESTIGATORS

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## PRINCIPAL INVESTIGATOR

**Evelyn D. Brown (formerly Biggs)**

The Principal Investigator is responsible for all project tasks and objectives.
Responsible for meeting project objectives and tasks; formulation of publication.

**Education:**

B.S. Zoology and Chemistry, University of Utah, Salt Lake City, 1977
M.S. Fisheries Biology and Aquacultural Engineering, Oregon State University, Corvallis, OR, 1980
Current Ph.D. candidate in Fisheries at University of Alaska, Fairbanks

**Experience:**

Research Associate, University of Alaska, Fairbanks, 1995 to the present.
Herring and Fisheries Research Biologist, Alaska Department of Fish and Game, Cordova, Alaska from 1985 to 1995.
Principal Investigator, Injury to Prince William Sound Herring from the *Exxon Valdez* Oil Spill, NRDA FS 11, 1989–1992.
Fisheries Biologist, Florida Department of Natural Resources, St. Petersberg, Florida, 1987–1988; hydroacoustics.
Fisheries Management Biologist, Metlakatla Indian Community, Annette Island, Alaska, 1980–1982.

**Field Experience:**

Aerial surveys; P.I. and primary surveyor, single engine aircraft; 1988–present.
U.W. Dive Surveys; P.I. and dive officer for ADFG dive program; 1988–1995.
Shipboard surveys; small vessels (30–60 ft); P.I. on 2, participated in over 12; last decade.
Large shipboard surveys; over 100 ft; participant; 1983 GOA and 1998 SE Alaska.
Skiff work; participated annually in solo and team operations of marine research from skiffs from 1979 to the present.
Familiarity with a variety of marine electronics from acoustics, side-scan sonars, GPS, and computerized navigation to a Compact Airborne Spectrographic Imager (CASI).

**Selected Publications:**

Brown, E.D., G.A. Borstad, K.D.E. Stokesbury, and B.L. Norcross. Accepted, manuscript in prep. Calibrating and improving the utility of aerial surveys via the use of CASI, videography, and acoustics in American Fisheries Society Symposium 00:00 (1998 in Hartford, Connecticut).
Brown, E. D., G.A. Borstad, and B.L. Norcross. In prep. Assessment of forage fish distribution and abundance using aerial surveys: survey design and methodology. (To be submitted to Ecological Applications).
Brown, E.D. , S. Vaughan, and B.L. Norcross. In press. Annual and seasonal spatial variability of herring, other forage fish, and seabirds in relation to oceanographic regimes in Prince William Sound, Alaska *in* Ecosystem Considerations in Fisheries Management, AFS/Lowell-Wakefield Symposium 00:00 (1998 in Anchorage, Alaska).

Stokesbury, K. D. E., J. Kirsch, E. D. Brown, G. L. Thomas, B. L. Norcross. Accepted. Seasonal variability in Pacific herring (*Clupea pallasi*) and walleye pollock (*Theragra chalcogramma*) spatial distributions in Prince William Sound, Alaska. Fisheries Research 00:00.

Brown, E.D., T.T. Baker, J.E. Hose, R.M. Kocan, G.D. Marty, M.D. McGurk, B.L. Norcross, and J. Short. 1996. Injury to the early life history stages of Pacific herring in Prince William Sound after the *Exxon Valdez* oil spill. Am. Fish. Soc. Symp. 18. pp. 448–462.

Brown, E.D., B.L Norcross, and J.W. Short. 1996. An introduction to studies on the effects of the *Exxon Valdez* oil spill on early life history stages of Pacific herring, *Clupea pallasi*, in Prince William Sound, Alaska. *Can J. Fish. Aq. Sci.* 53: 2337–2342

Brown, E.D. and E. M. Debeves. In press. Effects of the *Exxon Valdez* oil spill on in situ survival of Pacific herring (*Clupea pallasi*) eggs. *Can J. Fish. Aq. Sci.*

**Brenda L. Norcross**

The Co-Principal Investigator will review survey design, data, and analysis; review reports and publications.

**Education:**

A.B., Biology, MacMurray College, Jacksonville, Illinois, 1971.

M.S., Biology, St. Louis University, St. Louis, Missouri, 1976.

Ph.D., Marine Science, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1983.

**Experience:**

Associate Professor, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 1996–present.

Assistant Professor, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 1989–1996.

Assistant Professor, Division of Biological Oceanography and Fisheries Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1984–1988.

**Field Experience:**

One fisheries vessel, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, underwater camera (Prince William Sound, 7 days), 1998.

One – five fisheries vessels, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, underwater camera, aerial surveys (Prince William Sound, 34 days), 1997.

Five fisheries vessels, Principal Investigator, Pelagic fish, zooplankton, hydroacoustics, oceanography, aerial surveys (Prince William Sound, 60 days), 1996.

Six fisheries vessels, Principal Investigator, Pelagic fish, hydroacoustics, oceanography, aerial surveys (Prince William Sound, 22 days), 1995.

**Selected Publications:**

Norcross, B.L. and F.J. Mueter. 1999. The use of an ROV in the study of juvenile flatfishes. *Fish. Res.* In press.

Foy, R.J. and B.L. Norcross. 1999. Spatial and temporal differences in the diet of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Can. J. Zoolog.* In press.

Norcross, B.L., J.E. Hose, M. Frandsen and E. Brown. 1996. Distribution, abundance, morphological condition and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the *Exxon Valdez* oil spill. *Can. J. Fish. Aquat. Sci.* 53:2376–2387.

Brown, E.D., B.L. Norcross and J.W. Short. 1996. Conditions affecting the distribution of oil from the *Exxon Valdez* spill and exposure of Pacific herring, *Clupea pallasi*, in Prince William Sound, Alaska. *Can. J. Fish. Aquat. Sci.* 53:2337–2342.

Norcross, B.L. and M. Frandsen. 1996. Distribution and abundance of larval fishes in Prince William Sound, Alaska during 1989 after the *Exxon Valdez* oil spill. *In* S.D. Rice, R.B. Spies, D.A. Wolfe and B.A. Wright (eds.). *Exxon Valdez* Oil Spill Symposium Proceedings. *Am. Fish. Soc. Symp.* 18:463–486.

## LITERATURE CITED

Brown, E.D., B.L. Norcross, and J.W. Short. 1996a. An introduction to studies on the effects of the *Exxon Valdez* oil spill on early life history stages of Pacific herring, *Clupea pallasi*, in Prince William Sound, Alaska. Can J. Fish. Aq. Sci. 53: 2337–2342.

Brown, E.D., and seven other co-authors. 1996b. Injury to the early life history stages of Pacific herring in Prince William Sound after the *Exxon Valdez* Oil Spill. Am. Fish. Soc. Symp. No. 18. pp. 448–462.

Cooney, R.T. 1997. Sound Ecosystem Assessment (SEA) – an integrated science plan for the restoration of injured species in Prince William Sound. FY96 Annual Report for the *Exxon Valdez* Trustee Council, Anchorage, Alaska. 620 pp.

Cooney, R.T., K.O. Coyle, E. Stockmar, and C. Stark. In preparation. Seasonality in surface-layer net zooplankton communities in Prince William Sound, Alaska. To be submitted to Fisheries Oceanography.

Foy, R.J. and B.L. Norcross. In press. Spatial and temporal variability in the diet of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Can. J. Zool.* 00: 00.

Hastie, T.J. and R.J. Tibshirani. 1990. Generalized Additive Models. Chapman and Hall, New York, New York. 335 pp.

Iverson, S.J., K.J. Frost, S. Land, C. Field, and W. Blanchard. 1998. The use of fatty acid signatures to investigate foraging ecology and food webs in Prince William Sound, Alaska: Harbor seals and their prey. *In* Frost et. al. (eds) Monitoring, Habitat Use and Trophic Interactions of Harbor Seals in Prince William Sound, Alaska. Restoration Project 97064 Annual Report, *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Jacobson, L.D. and A.D. MacCall. 1995. Stock-recruitment models for Pacific sardine (*Sardinops sagaz*). *Can. J. Fish. Aquat. Sci.* 52: 566–577.

Kline, T.C. 1998. Temporal and spatial variability of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ in pelagic biota of Prince William Sound, Alaska. *In:* Steve Brandt and Doran Mason (eds) Space, Time, and Scale: New Perspectives in Fish Ecology and Management, *Can. J. Fish. Aquat. Sci.*

Rothschild, B.J., S.G. Smith, and H. Li. 1996. The application of time-series analysis to fisheries population assessment and modeling, *pp.* 354–402 *in* Stock Assessment Quantitative Methods and Applications for Small-Scale Fisheries (V.F.Gullucci, S.B. Saila, D.J. Gustafson, and B.J. Rothschild *eds.*), CRC Lewis Publishers, New York, New York.

Stokesbury, K.D.E., E.D. Brown, R.J. Foy, and B.L. Norcross. 1997. Juvenile herring growth and habitats, Restoration Project 95320T Annual Report, Chapter 11 *in* Cooney, R.T. 1997. Sound Ecosystem Assessment (SEA) – an integrated science plan for the restoration of injured species in Prince William Sound. FY96 Annual Report for the *Exxon Valdez* Trustee Council, Anchorage, Alaska. 75 pp.

Swartzman, G., C. Huang, and S. Kaluzny. 1992. Spatial analysis of Bering Sea groundfish survey data using generalized additive models. *Can. J. Fish. Aquat. Sci.* 49: 1366–1378.

Vaughan, S.L., K.E. Osgood, S.M. Gay, and L.B. Tuttle. In preparation. Seasonal variability of the large scale circulation and water mass variability in Prince William Sound, Alaska.

Vaughan, S.L., C.N.K. Mooers, J. Wang, S.M. Gay, and L.B. Tuttle. In preparation. Physical oceanography synthesis paper – Sound Ecosystem Assessement Program. To be submitted to Fisheries Oceanography.

**2000 EXXON VALDEZ TRI E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $44.9 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | | $44.9 |
| General Administration | | $3.1 |
| Project Total | | $48.0 |
| Full-time Equivalents (FTE) | | 0.5 |
| Other Resources | | |

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

Dollar amounts are shown in thousands of dollars.

Comments:

**FY00**

Prepared:

Project Number: 00375
Project Title: Effect of Herring Egg Distribution and Ecology on Year-Class Strength and Adult Distribution
Agency: Alaska Department of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**2000 EXXON VALDEZ TR E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Budget Category: | Authorized FY 1999 | Proposed FY 2000 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | | $31.6 | | | | | | |
| Travel | | $2.8 | | | | | | |
| Contractual | | $1.0 | | | | | | |
| Commodities | | $0.5 | | | | | | |
| Equipment | | $0.0 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | | $35.9 | | | Estimated FY 2001 | Estimated FY 2002 | | |
| Indirect | | $9.0 | | | | | | |
| Project Total | | $44.9 | | | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.5 | | | | | | |
| | 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.

**FY00**

Prepared:

Project Number: 00375
Project Title: Effect of Herring Egg Distribution and Ecology on Year-Class Strength and Adult Distribution
Name: Evelyn Brown

FORM 4A
Non-Trustee
SUMMARY

**2000 EXXON VALDEZ TR :E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 2000 |
| Brown, E. | Principal Investigator/Manager | | 2.5 | 6.2 | | 15.5 |
| Norcross, B. | Co-Principal Investigator/Assoc. Prof. | | 0.25 | 8.5 | | 2.1 |
| Moreland, S. | Technician | | 2.0 | 4.3 | | 6.5 |
| Vallerino, M. | Computer Programmer | | 1.5 | 5.0 | | 7.5 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| Subtotal | | | 6.3 | 24.0 | 0.0 | |
| | | | | | **Personnel Total** | $31.6 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 2000 |
| Fairbanks to Anchorage | 220.0 | 1 | 5 | 121.0 | 0.8 |
| Registration (Lowell Wakefield Seminar) | | | | | 0.2 |
| Fairbanks to Nevada | 0.8 | 1 | 5 | 118.0 | 1.4 |
| Car rental | | | | | 0.2 |
| Registration (AFS Conference) | | | | | 0.2 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $2.8 |

**FY00**

Prepared:

Project Number: 00375
Project Title: Effect of Herring Egg Distribution and Ecology on Year-Class Strength and Adult Distribution
Name: Evelyn Brown

FORM 4B
Personnel
& Travel
DETAIL

**2000 EXXON VALDEZ TR E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Communications | 0.2 |
| Publications | 0.7 |
| Copy/Reproduction | 0.1 |
| **Contractual Total** | $1.0 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2000 |
| Software upgrades | 0.5 |
| **Commodities Total** | $0.5 |

**FY00**

Prepared:

Project Number: 00375
Project Title: Effect of Herring Egg Distribution and Ecology on Year-Class Strength and Adult Distribution
Name: Evelyn Brown

FORM 4B
Contractual & Commodities DETAIL

**2000 EXXON VALDEZ TRI E COUNCIL PROJECT BUDGET**

October 1, 1999 - September 30, 2000

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | 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 |
| 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 | |
| | | |

**FY00**

Project Number: 00375
Project Title: Effect of Herring Egg Distribution and Ecology on Year-Class Strength and Adult Distribution
Name: Evelyn Brown

FORM 4B
Equipment
DETAIL

Prepared: