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FY 2000 Final Work Plan

DPDs and Budgets

approved TC 8-9-99

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

Project Number:	00340
Restoration Category:	Monitoring
Proposer:	T. Weingartner/UAF
Lead Trustee Agency:	ADFG
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	Cont'd
Duration:	3rd yr. 4 yr. project
Cost FY 00:	$65.9
Cost FY 01:	$72.0
Cost FY 02:	$0.0
Geographic Area:	Resurrection Bay
Injured Resource/Service:	All

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 oil spill. This variability is best quantified from long time series such as that gathered over 29 years at a hydrographic station (GAK1) near Seward. This project 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 project. 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)

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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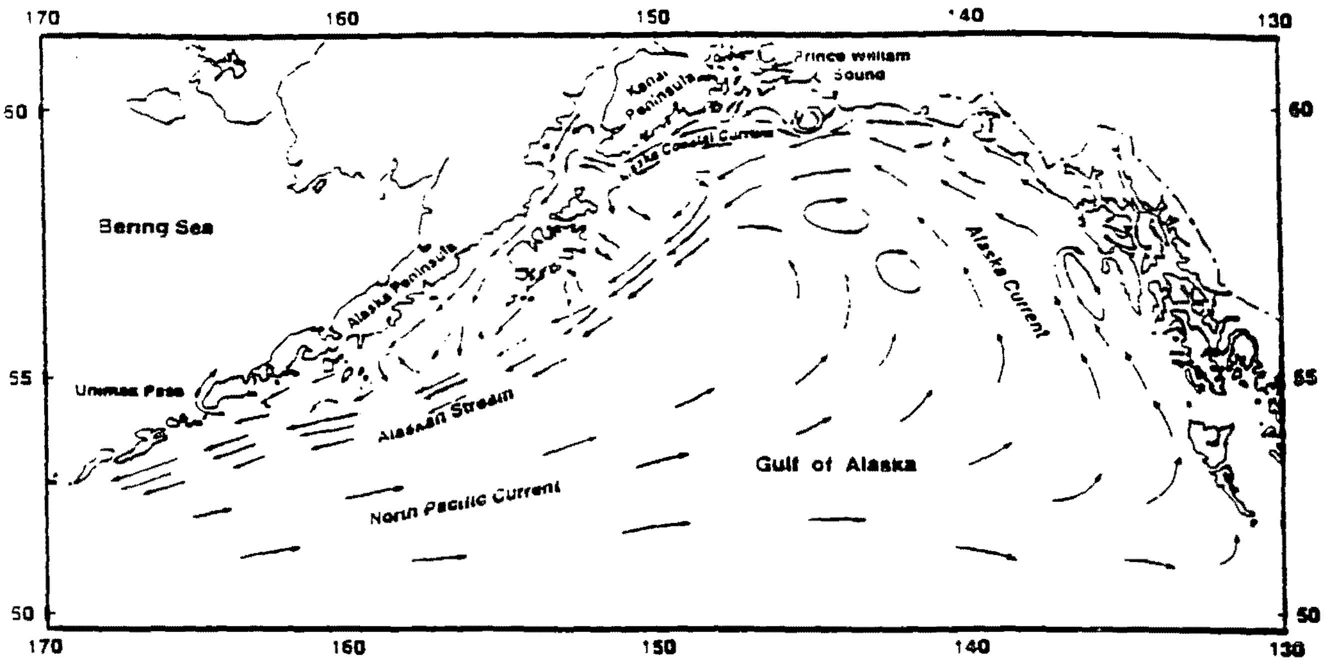


Figure 1. Schematic of the circulation of the Northeast Pacific and Gulf of Alaska (From Reed and Schumaker, 1986).

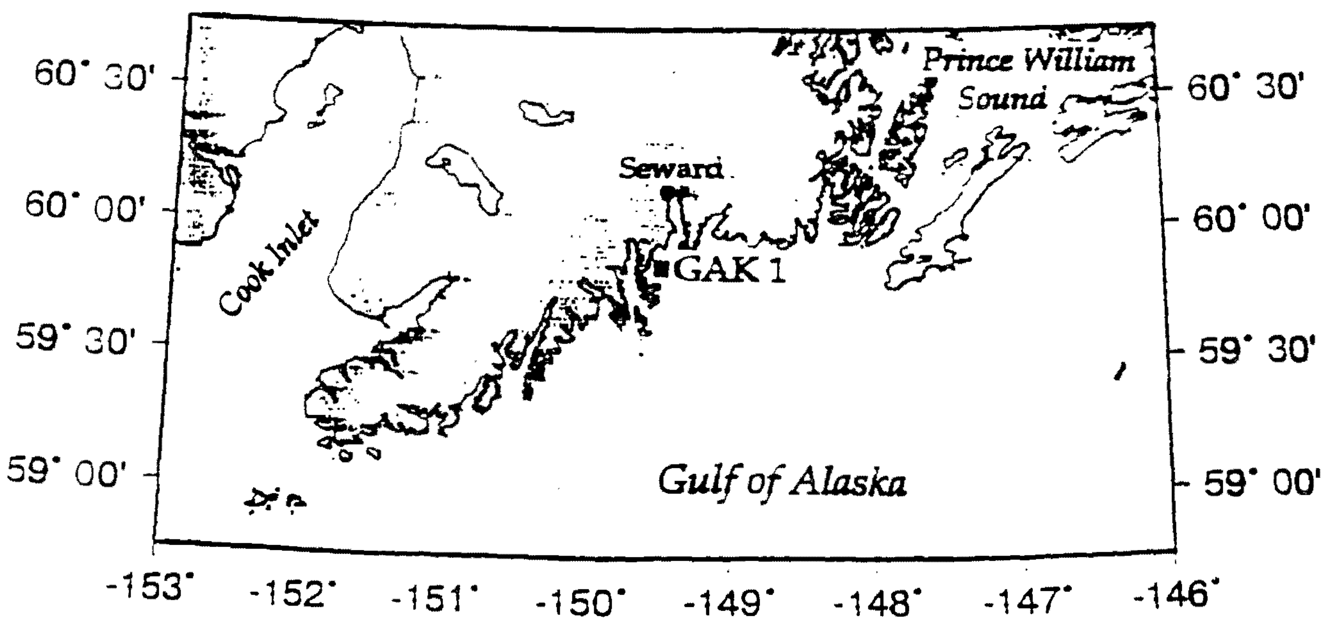


Figure 2. Map showing location of hydrographic station GAK1 in relation to Prince William Sound, Cook Inlet and Seward.

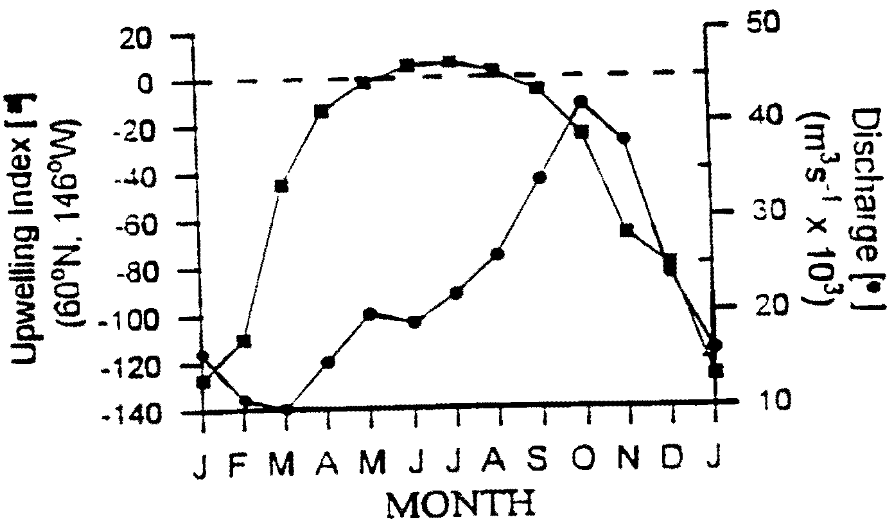
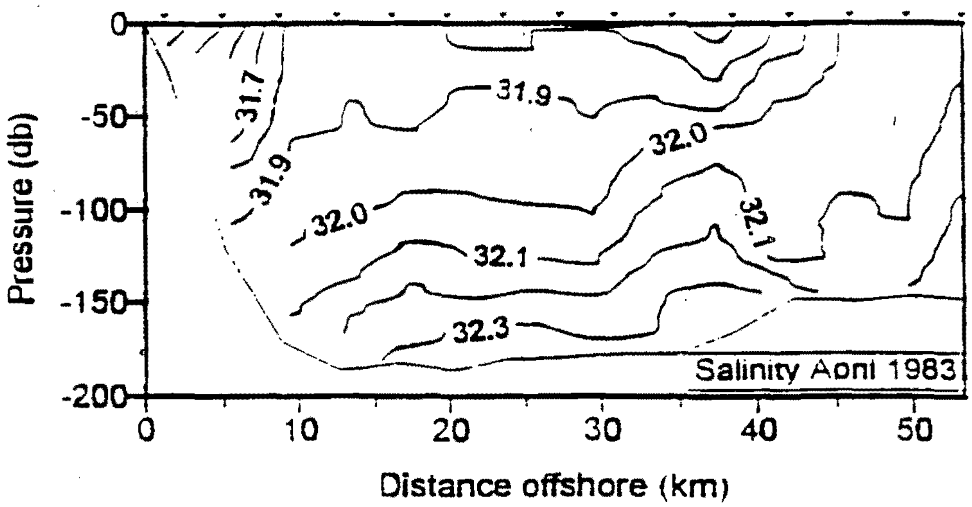


Figure 3. Mean monthly values of the upwelling index (from 1946–1995) and the estimated freshwater discharge (from 1930–1992) into the Gulf of Alaska using the hydrology model of Royer (1982).



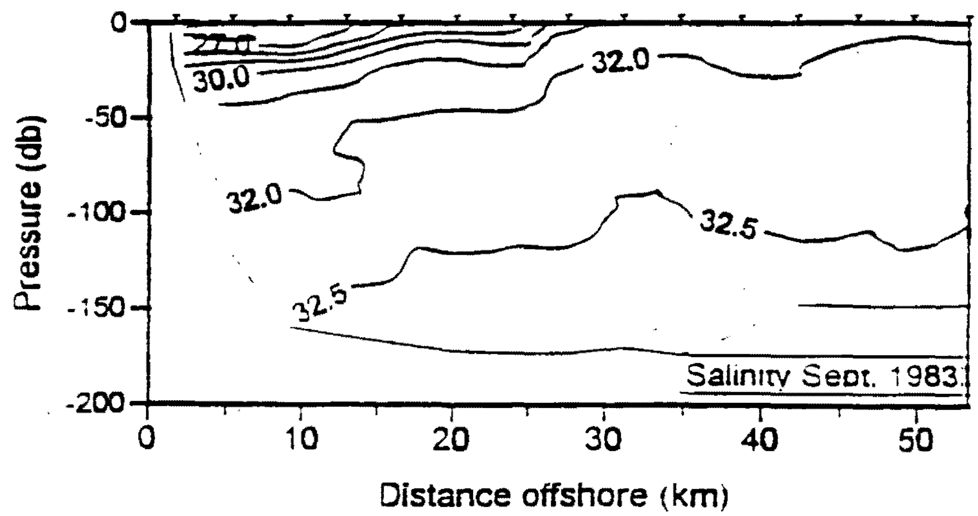


Figure 4. Contours of salinity as a function of depth and position in the Gulf of Alaska on a cross-shelf transect near GAK1. The upper panel is from April 1983 and the lower panel is from September 1993.

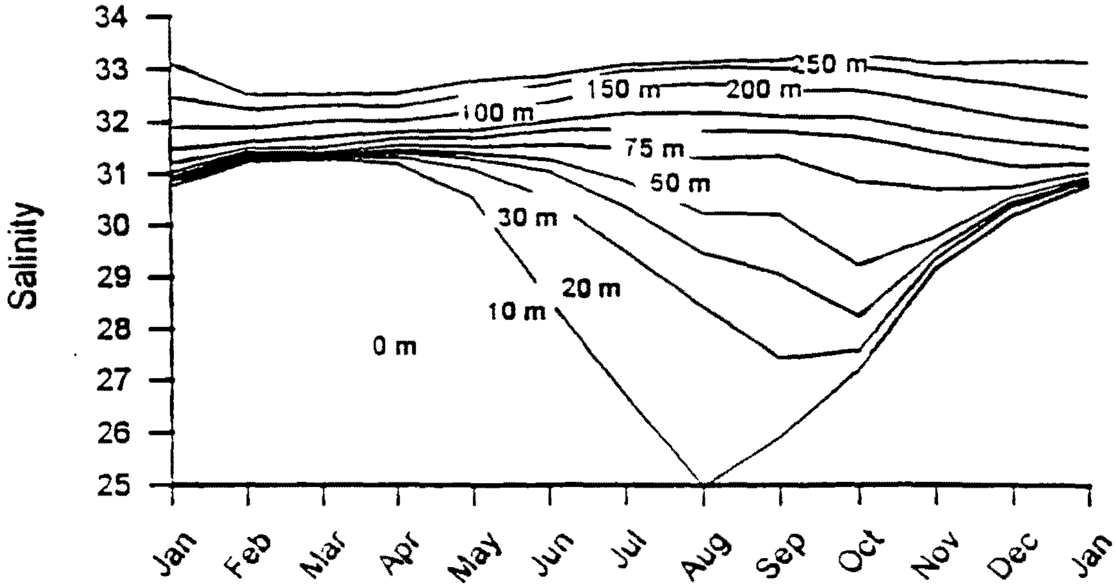


Figure 5. Mean monthly salinity at GAK1 as a function of depth. The means are computed from data collected between 1970 and 1996.

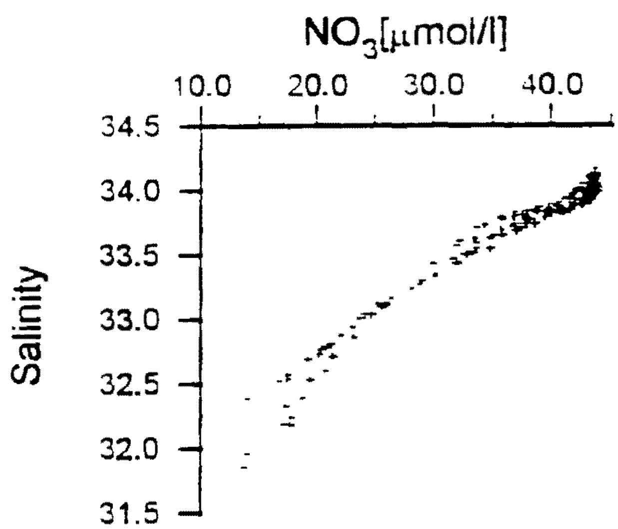


Figure 6. NO_3–salinity scatter plot from the shelf and slope of the northwest Gulf of Alaska in May–June 1993.

Revision 7- -99
Approved TC 8-9-99

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

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$61.6						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$61.6			Estimated FY 2001	Estimated FY 2002		
General Administration		$4.3						
Project Total	$0.0	$65.9						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Prepared:

Project Number: 00340
Project Title: Long-Term Oceanographic Monitoring of GOA Ecosystem
Agency: ADFG

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		$37.5						
Travel		$2.0						
Contractual		$7.7						
Commodities		$2.1						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$49.3			Estimated FY 2001	Estimated FY 2002		
Indirect		12.3 ~~$12.4~~						
Project Total		61.6 ~~$61.7~~			$67.3			
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

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

FORM 4A
Non-Trustee
SUMMARY

ared:

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Personnel Costs:							
	Name	Position Description		Months Budgeted	Monthly Costs	Overtime	Proposed FY 2000
	Weingartner, T.	Principal Investigator/Assistant Prof.		2.0	6.4		12.9
	Vallarino, M.	Computer programmer		2.0	5.3		10.9
	Leech, D.	Mooring and marine technician		2.3	5.2	0.3	13.7
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		6.3	16.9	0.3	
						Personnel Total	$37.5

Travel Costs:		Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FY 2000
	Description					
	R/T Fairbanks to Anchorage	300.0	1	3	120.0	0.7
	Fairbanks to San Antonio, TX	750.0	1	5	125.0	1.3
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$2.0

FY00

Prepared:

Project Number: 00340 -- Revision
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 TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Contractual Costs:	Proposed
Description	FY 2000
Little Dipper (4 full days @ $500/day and 2 half days @ $250/hday)	2.5
CTD calibration (SBE-25)	0.6
Microcat calibration (6 @ $600 ea.)	3.6
Shipping (R/T Seward to Seattle, CTD and MicroCats)	1.0
Contractual Total	$7.7

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 -- Revision
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
			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

Prepared:

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

FORM 4B
Equipment
DETAIL

00341

approved TC 8-9-99

Harbor Seal Recovery: Controlled Studies of Health and Diet

Project Number:	00341
Restoration Category:	Research
Proposer:	M. Castellini/UAF
Lead Trustee Agency:	ADFG
Cooperating Agencies:	None
Alaska SeaLife Center:	Yes
New or Continued:	Cont'd
Duration:	3rd yr. 4 yr. project
Cost FY 00:	$216.1
Cost FY 01:	$90.1
Cost FY 02:	$0.0
Geographic Area:	Kenai Peninsula, Seward
Injured Resource/Service:	Harbor seal

ABSTRACT

This project will continue a long-term study currently underway at the Alaska SeaLife Center to quantify the impact of specific fish diets on the health and body condition of harbor seals. Even though health status biomarkers for marine mammals in Prince William Sound were established during field trials (Project /001), the critical test of how markers vary in an individual as a result of eating specific prey has not been conducted. The project 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 will focus 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 (±S.D; wet mass basis) for herring used in the first feeding trial was 16.0 ± 1.5 % (n = 5), compared to pollock which was 5.0 ± 0.9% (n = 5). Mean energy density (± S.D.; wet mass basis) for herring was 9.2 ± 0.8 kJ/g (n= 10) compared to 5.2 ± 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

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Revision 8-99
approved TC 8-9-99

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

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$113.3						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$113.3			Estimated FY 2001	Estimated FY 2002		
General Administration		$7.9						
Project Total	$0.0	$121.2			$90.1	$0.0		
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.

Student personnel costs include resident tuition of $3,216 per year.

TOTAL PROJECT COST: $121.2
+ 94.9 ASLC bench fees
$216.1

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		$53.5						
Travel		$7.2						
Contractual		$22.6						
Commodities		$7.3						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$90.6			Estimated FY 2001	Estimated FY 2002		
Indirect		$22.7						
Project Total	$0.0	$113.3			$93.0	$0.0		
Full-time Equivalents (FTE)		1.5						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

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

Student personnel costs include resident tuition of $3,216 per year.

FY00

Prepared:

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

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
						0.0
Castellini, M	Principal Investigator/Professor		2.5	8.0		20.0
Castellini, J. M.	Research Associate		3.0	4.7		14.1
	Ph.D. Student		12.0	1.6		19.2
						0.0
	Adjustment to recognize rounding					0.2
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		17.5	14.3	0.0	
					Personnel Total	$53.5

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
					0.0
Fairbanks to Anchorage for annual EVOS meeting	0.3	1	5	0.1	0.8
Fairbanks to Anchorage for EVOS workshop	0.3	1	5	0.1	0.8
Fairbanks to Seward to oversee research at the ASLC	0.3	9	18	0.1	4.5
Fairbanks to Maui for Marine Mammal Conference	0.6	1	5	0.1	1.1
					0.0
Adjustment to recognize rounding					0.0
					0.0
					0.0
					0.0
				Travel Total	$7.2

FY00

Prepared:

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

FORM 4B
Personnel
& Travel
DETAIL

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

Contractual Costs: Description	Proposed FY 2000
Contractual services (blood - veterinary analysis)	15.0
Contractual services (prey analysis)	1.9
Contractual services (additional animal services)	3.2
Communications	1.0
Publication/disseminations	1.5
Contractual Total	$22.6

Commodities Costs: Description	Proposed FY 2000
Laboratory expendables for collection of blood samples	3.0
Laboratory expendables for collection and storage of other samples (fece, urine, prey)	1.5
Laboratory expendables for analysis of samples	2.8
Commodities Total	$7.3

FY00

Prepared:

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

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
			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

Prepared:

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

FORM 4B
Equipment
DETAIL

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$88.7						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$88.7			Estimated FY 2001	Estimated FY 2002		
General Administration		$6.2						
Project Total	$0.0	$94.9						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Prepared:

Project Number: 00341
Project Title: Harbor Seal Studies of Health & Diet -- ASLC Bench Fee Component
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

approved TC 8-9-99

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

Project Number:	00347-CLO
Restoration Category:	Research
Proposer:	R. Heintz/NOAA
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	Cont'd
Duration:	3rd yr. 3 yr. project
Cost FY 00:	$35.5
Cost FY 01:	$0.0
Cost FY 02:	$0.0
Geographic Area:	Prince William Sound, lower Cook Inlet
Injured Resource/Service:	Various

ABSTRACT

This is the closeout 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, the spatial and temporal variability of fatty acid profiles in herring, sand lance, and zooplankton was examined and related to the nutritional condition of these forage fish. In FY 98, the spatial comparisons, which provided insight into the energetic differences in forage fish in disparate parts of Prince William Sound, were conducted. In FY 99, temporal comparisons which will provide information on the energetic changes that inevitably occur with seasonal, ontogenetic, and reproductive changes will be conducted. All these comparisons are based on samples collected by APEX (Project /163) investigators. In FY 00, closeout will entail a statistical analysis and report on the spatial, temporal, and ontogenetic variation of data.

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
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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.

Rev'd 7-8-99
approved TC 8-9-99

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel	$57.2	$27.5						
Travel	$6.6	$3.9						
Contractual	$5.0	$0.0						
Commodities	$14.9	$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$83.7	$31.4			Estimated FY 2001	Estimated FY 2002		
General Administration	$8.9	$4.1						
Project Total	$92.6	$35.5			$0.0			
Full-time Equivalents (FTE)		0.3						
	Dollar amounts are shown in thousands of dollars.							
Other Resources		$35.9						

Comments:
NOAA Contribution:

Habitat Investigation Program manager. S. Rice, 0.5 mon = $6.1K, Principle Investigator, R. Heintz 2.5 mo @ 18.3 K, Senior Analytical Chemist, M. Larsen, 1.0 mo @ 6.7 K, Senior Research chemist, J. Short 0.5 mo @ 4.7K for a total NOAA contribution of 35.9 K

FY00

Prepared: 7/6/99

Project Number: 00347
Project Title: Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Composition and Quality at Different Trophic Levels
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2000 EXXON VALDEZ TRUSTEE 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
						0.0
R Heintz	Co-PI Fishery Research Biologist	12/3	1.0	7.4		7.4
M. Larsen	Co-PI Fishery Research Biologist	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		4.0	20.8	0.0	
					Personnel Total	$27.5

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
Anchorage, EVOS Symposium, (Larsen)	0.5	1	4	0.2	1.3
Miscellaneous (Car rental, telephone chgs, POV mileage, etc)					0.4
					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
Fish Symposium	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	$3.9

FY00

Prepared: 7/6/99

Project Number: 00347
Project Title: Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Composition and Quality at Different Trophic Levels
Agency: NOAA

FORM 3B
Personnel
& Travel

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

FORM 3B
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
			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	2	
GC/MS	1	
HPLC	1	

FY00

Project Number: 00347
Project Title: Fatty Acid Profile and Lipid Class Analysis for Estimating Diet Composition and Quality at Different Trophic Levels
Agency: NOAA

FORM 3B
Equipment
DETAIL

Prepared: 7/6/99

Revision 7-8-99
approved TC 8-9-99

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

Project Number:	00348-CLO
Restoration Category:	Research
Proposer:	M. Ben-David, T. Bowyer, L. Duffy/UAF
Lead Trustee Agency:	ADFG
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	Cont'd
Duration:	3rd yr. 3 yr. project
Cost FY 00:	$50.6
Cost FY 01:	$0.0
Cost FY 02:	$0.0
Geographic Area:	Prince William Sound
Injured Resource/Service:	River otters

ABSTRACT

This project will complete data analyses and manuscript preparation for Project /348, which was designed to explore the effects of oil contamination on physiological responses in river otters. Fifteen captive otters were exposed to two levels of oil contamination under controlled conditions at the Alaska SeaLife Center. Samples of blood, tissues and feces were collected for analysis of biomarkers and for immunological examinations. A wealth of data was collected during the experiment phase. Completion of data analyses and publication of results are especially important in light of the recent listing by the 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 4 weeks. Release occurred on the week of March 21, 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 on 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. 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.

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 FY00.

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.

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 3 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: Bioindicators

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: 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: Journal of Wildlife Diseases

Other publications resulting from this project:

7. Title: Post-release survival of river otters: effects of oiling or captivity?
   Authors: M. Ben-David and G. M. Blundell
   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.

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.

9. Title: Group living in coastal river otters: effect of group size on foraging success
   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.
   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. R. Rostein, M. Ben-David, and J. A. Randall
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 and a Wildlife Diseases 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.

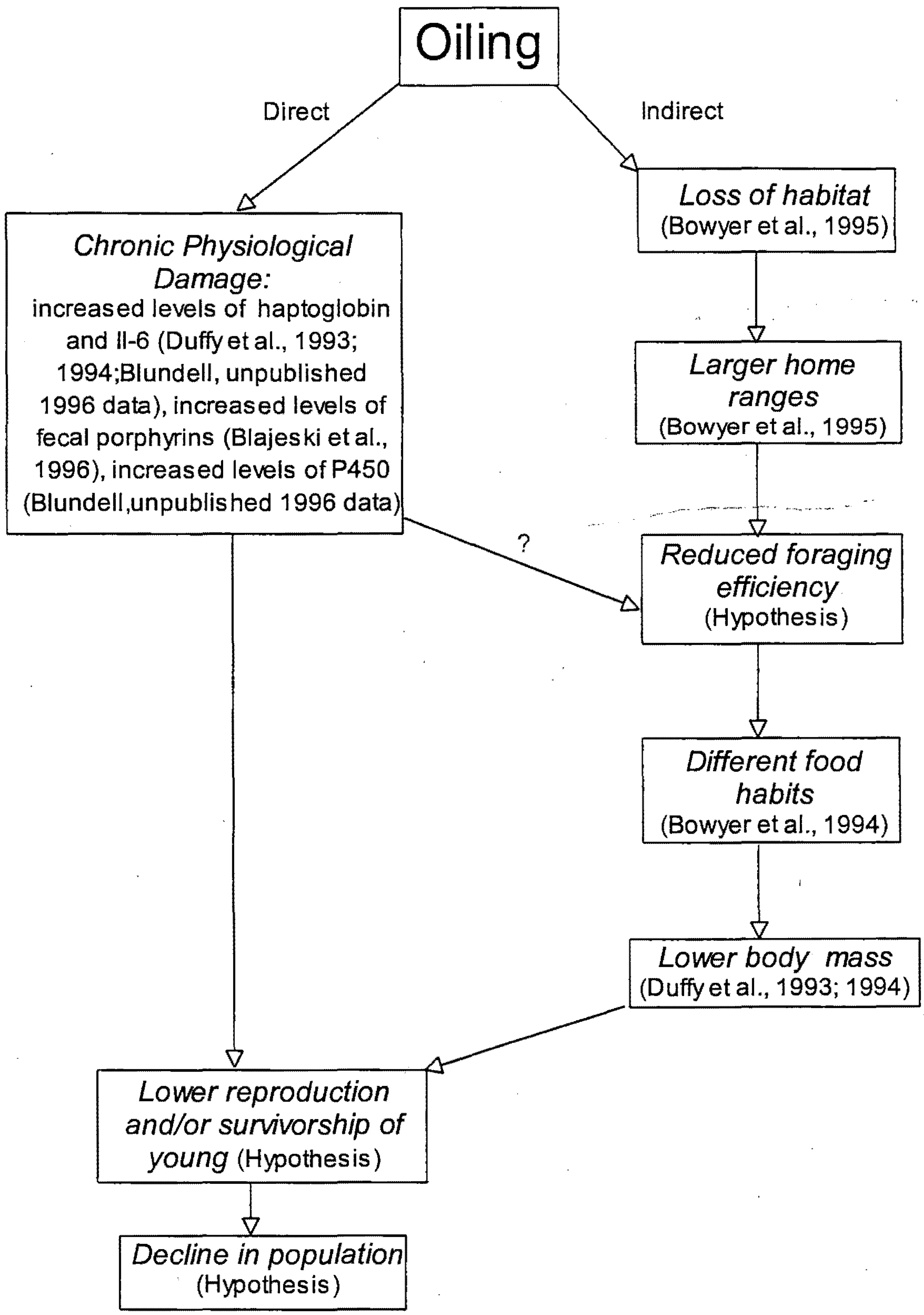

Fig. 1 - Possible pathways for the effect of oiling on river otters in Prince William Sound, Alaska

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

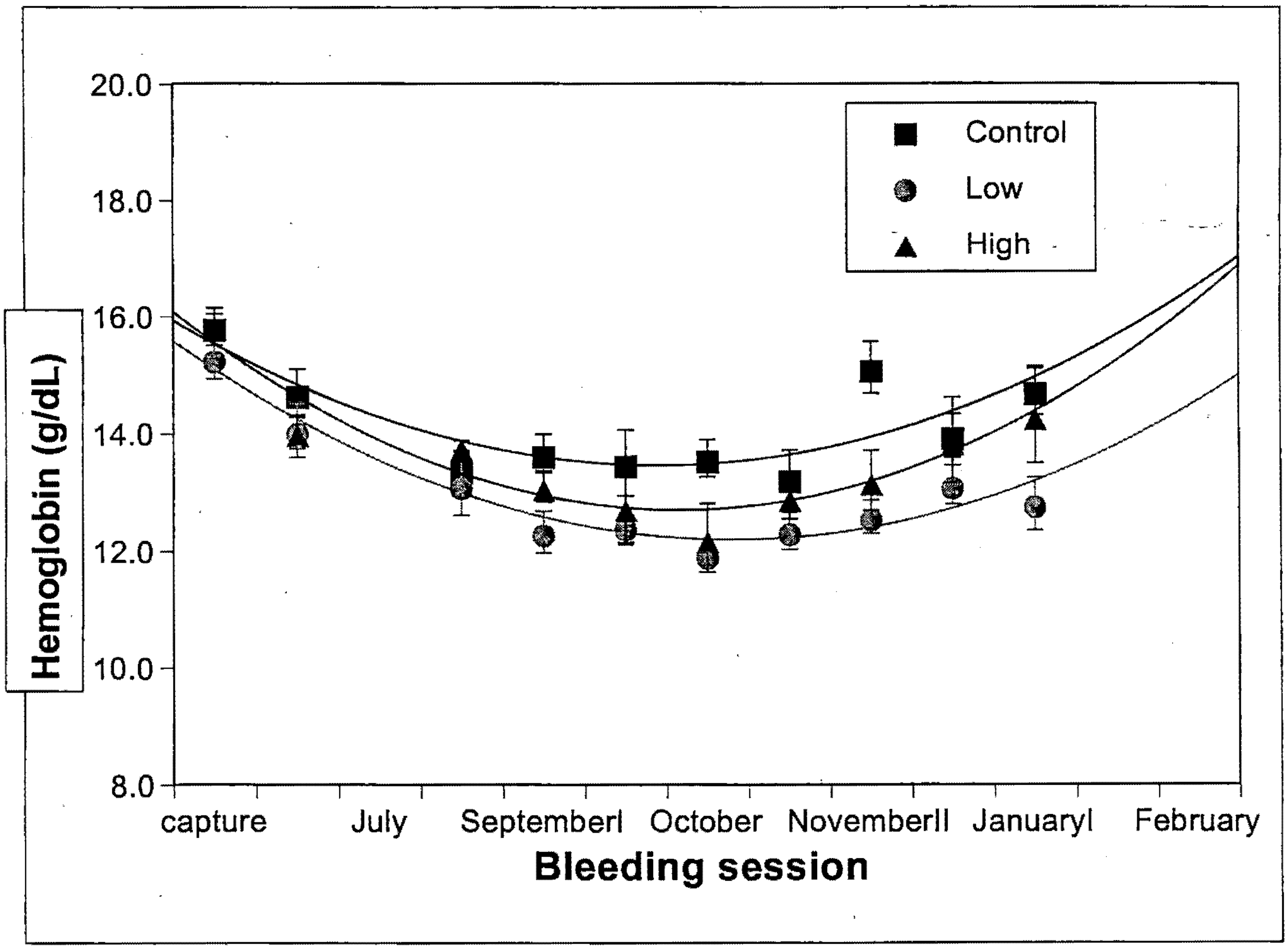

Fig. 3 – Levels of hemoglobin in blood of captive river otters exposed to 3 levels of hydrocarbons in their diet.

PRINCIPAL INVESTIGATORS

Dr. Merav Ben-David
Institute of Arctic Biology
University of Alaska Fairbanks
311 Irving Bldg. UAF
Fairbanks, AK 99775
(907) 474 - 6669 fnmb@aurora.alaska.edu

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
Institute of Arctic Biology
University of Alaska Fairbanks
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Fairbanks, AK 99775
(907) 474 - 5311 ffrtb@aurora.alaska.edu

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 K. Duffy
Department of Chemistry and Biochemistry
Box 756160
University of Alaska
Fairbanks, AK 99775
(907) 474-7525fychem@acad3.alaska.edu

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.

Revision 7-8-99
Approved : 8-9-99

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

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$47.3						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$47.3			Estimated FY 2001	Estimated FY 2002		
General Administration		$3.3						
Project Total	$0.0	$50.6						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Project Number: 00348 -CLO
Project Title: Responses of River Otters to Oil Contamination
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Revision 7/8/99

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000
Personnel	$71.7	$29.0
Travel	$10.7	$1.8
Contractual	$68.1	$4.0
Commodities	$10.8	$3.0
Equipment	$0.0	$0.0
Subtotal	$161.3	$37.8
Indirect	$32.5	$9.5
Project Total	$193.8	$47.3
Full-time Equivalents (FTE)		0.6
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% 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. 4.75% of direct cost will be spent on attending workshops and professional meetings.

7/2/99

Ted DeLaca — Date
Director, Office of Arctic Research

6/25/99

Merav Ben-David — Date
Institute of Arctic Biology

FY00

Prepared:

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

FORM 4A
Non-Trustee
SUMMARY

6/25/99

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
	Merav Ben-David	Principal Investigator - Data analysis and rep		4.0	5.6		22.4
	Olav A. Ormseth	Research Technician - Report wirting (1 ms)		1.0	2.2		2.2
	Susanne Trillhose	Research Technician - Stable isotope lab ana		2.0	2.2		4.4
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
		Subtotal		7.0	10.0	0.0	
						Personnel Total	$29.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 2000
	Fairbanks to Anchorage - restoration workshop	0.3	1	3	0.1	0.6
	Fairbanks to lower 48 - professional meetings	0.8	1	4	0.1	1.2
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$1.8

FY00

Prepared:

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

FORM 4B
Personnel
& Travel
DETAIL

6/25/99 [illegible]

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

Contractual Costs:	Proposed
Description	FY 2000
Stable isotope analysis - Water research center, UAF, 150 samples @ $15.0 per sample	2.3
Testosterone analysis, Endocrinology lab, IAB, UAF 165 samples @ $10.0 per sample	1.7
Contractual Total	$4.0

Commodities Costs:	Proposed
Description	FY 2000
Publication costs 3 manuscripts @ 1,000.0 per one	3.0
Commodities Total	$3.0

FY00

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

FORM 4B
Contractual &
Commodities
DETAIL

5/4 [illegible]

New Eq ent Purchases:

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

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.			0.0
		New Equipment Total	$0.0

Existing Equipment Usage:

Description	Number of Units	
Masspectrometer (Water Research Center - UAF)		
Computer	2	
	1	

FY00	Project Number: 00348 Project Title: Responses of river otters to oil contamination Name: Ben-David, IAB - UAF	FORM 4B Equipment DETAIL

6/25/99 [illegible]

approved TL 8-9-99

The *Exxon Valdez* Oil Spill: Guidance for Future Research Activities

Project Number:	00360-BAA
Restoration Category:	Research
Proposer:	C. Elfring/Polar Research Board, NRC
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	New
Duration:	1st yr. 2 yr. project
Cost FY 00:	$307.4
Cost FY 01:	$131.5
Cost FY 02:	$0.0
Geographic Area:	All
Injured Resource/Service:	All

ABSTRACT

The National Research Council's Polar Research Board and Board on Environmental Science and Toxicology will appoint a special committee to review the scope, content, and structure of the draft science plan the 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 will become familiar with the overall program of damage assessment and restoration research and monitoring activities that has been sponsored by the Council. The committee will prepare a final report with the 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 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

Revised 6-30-99
approved TC 9-99

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

Budget Category:	Authorized FY 1999	Proposed FY 2000
Personnel		$0.0
Travel		$0.0
Contractual		$286.6
Commodities		$0.0
Equipment		$0.0
Subtotal	$0.0	$286.6
General Administration		$18.2
Project Total	$0.0	$304.8
Full-time Equivalents (FTE)		0.0
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

		Estimated FY 2001	Estimated FY 2002		

Dollar amounts are shown in thousands of dollars.

Comments:

FY00

Project Number: 00360-BAA
Project Title: Guidance for Future Research Activities
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Revision 6-30-99

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999- September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$73,754.0						
Travel		$103,890.0						
Contractual		$12,721.0						
Commodities		$600.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$190,965.0			Estimated FY 2001	Estimated FY 2002		
Indirect		$95,642.0						
Project Total	$0.0	$286,607.0			$122,859.0			
Full-time Equivalents (FTE)		0.8						
	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:
/99

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

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
Chris Elfring	Director, PRB		12.0	2645.0		31,740.0
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%					15,730.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		48.0	4835.3	0.0	
					Personnel Total	$73,753.6

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
Anchorage Workshop in Winter 2000+Committee Meeting	1000.0	15	90	145.0	28,050.0
Anchorage (2 separate committee meetings/low season)	1000.0	30	120	145.0	47,400.0
Anchorage (1committee meeting/high season)	1000.0	15	60	224.0	28,440.0
					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	$103,890.0

FY00

Prepared:
6/30/99

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

FORM 4B
Personnel
& Travel
DETAIL

2 of 4

2000 EXXON VALDEZ TRUSTEE 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	5,814.0
Meeting Expenses (room rental, breaks, transportation, site visits)	3,650.0
Publications/computer research/searches	300.0
Contractual Total	$12,721.0

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

FY00

Prepared:
6/30/99

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 TRUSTEE 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
			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:
6/30/00

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

FORM 4B
Equipment
DETAIL

00371

Approved TC 8-9-99

Effects of Harbor Seal Metabolism on Stable Isotope Ratio Tracers

Project Number:	00371
Restoration Category:	Research
Proposer:	D. Schell/UAF
Lead Trustee Agency:	ADFG
Cooperating Agencies:	None
Alaska SeaLife Center:	Yes
New or Continued:	Cont'd
Duration:	2nd yr. 3 yr. project
Cost FY 00:	$163.1
Cost FY 01:	$96.3
Cost FY 02:	$0.0
Geographic Area:	Prince William Sound, Gulf of Alaska
Injured Resource/Service:	Harbor seal

ABSTRACT

A major concern with the use of stable isotope tracers in ecosystem studies is the fidelity with which 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, this project will seek specific conservative biomarkers such as essential amino acids or fatty acids that carry isotope ratios unmodified by metabolism. Amino acids labeled with 15N and 13C 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 three 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
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School of Fisheries and Ocean Sciences
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approved TC 9-99

2000 EXXON VALDEZ TRUSTEE 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	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$98.0			Estimated FY 2001	Estimated FY 2002		
General Administration		$6.9						
Project Total	$0.0	$104.9			$96.3			
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

Total Project Cost: $104.9
+ 58.2 ASLC bench fees
$163.1

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 TRUSTEE 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	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$78.4			Estimated FY 2001	Estimated FY 2002		
Indirect		$19.6						
Project Total	$0.0	$98.0			$90.0			
Full-time Equivalents (FTE)		1.4						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

The indirect rate is 25% TDC, as negotiated by the *Exxon Valdez* Oil Spill Trustee Council with the University of Alaska.
Student personnel costs include non-resident tuition of $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 TRUSTEE 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

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

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

Prepared:

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

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
			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:

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$54.4						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$54.4			Estimated FY 2001	Estimated FY 2002		
General Administration		$3.8						
Project Total	$0.0	$58.2						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Project Number: 00371
Project Title: Effecs of Harbor Seal Metabolism on Stable Isotope Ratio Tracers -- ASLC Bench Fee Component
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

approved TC 8-9-99

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

Project Number:	00375-CLO
Restoration Category:	Research
Proposer:	E. Brown, B. Norcross/UAF
Lead Trustee Agency:	ADFG
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	Cont'd
Duration:	2nd yr. 2 yr. project
Cost FY 00:	$48.0
Cost FY 01:	$0.0
Cost FY 02:	$0.0
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pacific herring

ABSTRACT

This project will examine the effect of Pacific herring egg distribution and abundance as well as oceanographic processes on year-class strength and adult distribution. Existing data will be used in the analysis. The findings will aid understanding of 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.

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, α 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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approved 8-9-99

2000 EXXON VALDEZ TRUSTEE 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)		0.0
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

		Estimated FY 2001	Estimated FY 2002		

Dollar amounts are shown in thousands of dollars.

Comments:

FY00

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

Prepared:

2000 EXXON VALDEZ TRUSTEE 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 TRUSTEE 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
						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
					0.0
				Travel Total	$2.8

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
Personnel
& Travel
DETAIL

Prepared:

2000 EXXON VALDEZ TRUSTEE 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 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
			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: 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:

Revision 7-9-99
approved TC 8-9-99

Prince William Sound Food Webs: Structure and Change

Project Number:	00393-BAA
Restoration Category:	Research
Proposer:	T. Kline/PWSSC
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	Cont'd
Duration:	2nd yr. 3 yr. project
Cost FY 00:	$153.7
Cost FY 01:	$127.7
Cost FY 02:	$0.0
Geographic Area:	Prince William Sound
Injured Resource/Service:	Pink salmon, Pacific herring

ABSTRACT

Recent research has shown that the oceanographic conditions connecting the northern Gulf of Alaska with Prince William Sound may affect recruitment and nutritional processes in fishes. Accordingly, food webs are subject to changes in carbon flow occurring between the Gulf of Alaska and Prince William Sound. This project seeks to (a) conduct retrospective analysis of Gulf of Alaska production shifts since the oil spill and (b) address ECOPATH model validation data gaps. These analyses will enable a better understanding of the ecological role of regime shift processes conjectured to be impeding the natural restoration of populations in Prince William Sound affected by the oil spill.

INTRODUCTION

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

Results from prior work

Juvenile herring and pollock are the dominant pelagic fishes in PWS and both consume zooplankton. Juvenile herring and pollock from PWS shifted in $^{13}C/^{12}C$ content between 1994 and 1995 from which a change in carbon source dependency was inferred (Fig. 1). Although both species shifted in concert to greater GOA dependency in 1995 than 1994, pollock were consistently less dependent on GOA carbon. Juvenile pollock and herring occupy different levels in the water column, have different schooling behavior, and recruit from the larval stage at different times, effecting access to a different forage-base as confirmed by the data. This difference may not be reflected in the species composition of diet but instead the where and when of the production cycle as integrated into the isotopic signature (Kline 1998), which reflects the assimilated carbon pool of the fish. The greater reliance on GOA-derived carbon in herring may reflect their dependence on carbon generated later in the season during the time when advection of GOA production was nearly the sole carbon source in 1995 as suggested by the data (Fig. 1). The concordant shift to greater GOA dependency by both species in 1995, Sound-wide, implied that system-wide bottom-up effects permeated the whole ecosystem due oceanographic processes.

The isotopic gradient between PWS and GOA had a consistent relationship in the 1994-1996 period except for May 1996 when the gradient reversed owing to a large magnitude change in the GOA signature (Fig. 2). Whereas PWS mean $^{13}C/^{12}C$ values ranged within 1 delta unit, and the difference between PWS and GOA averaged 3 delta units, the GOA mean value shifted in Spring 1996 by 5 delta units. This large shift reflected a change in phytoplankon fractionation during uptake of CO_2 which varies as a function of growth rate (Laws et al. 1995, Bridigare et al. 1997). Thus the productivity pattern during the spring bloom of 1996 was markedly different from other times. Large fluctuations in productivity in the GOA suggests large inconsistencies in food availability for consumers from year to year if these fluctuations are typical. Thus the question arises : Are fluctuations in GOA spring bloom productivity, as evidenced by changes in $^{13}C/^{12}C$, typical?

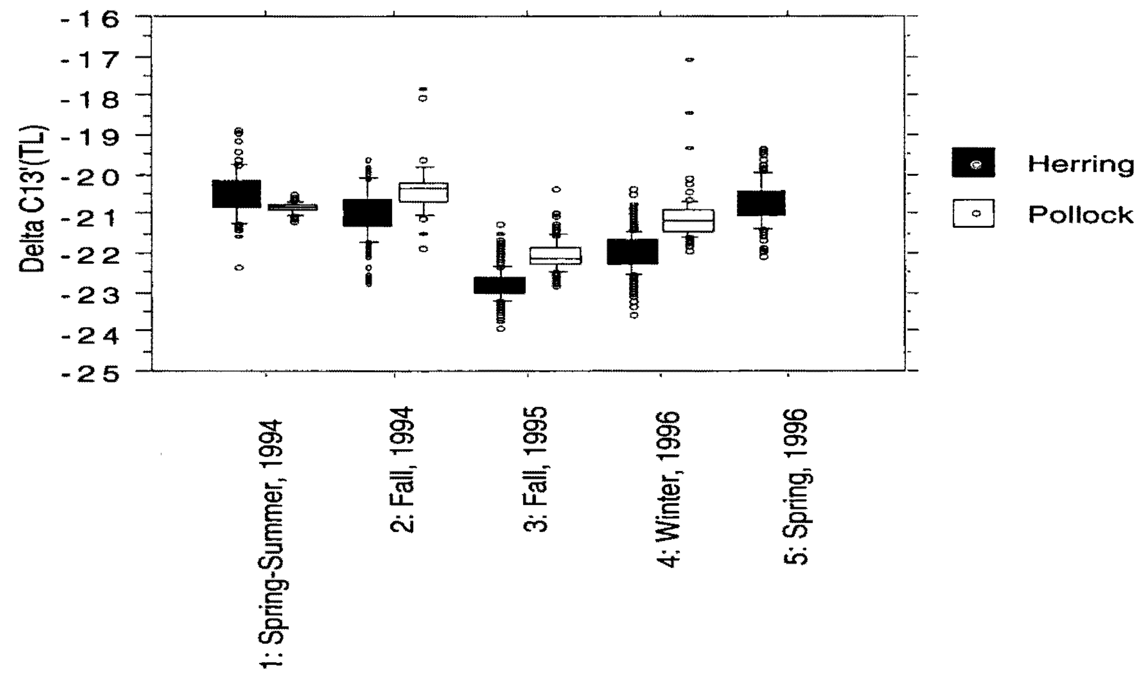

Figure 1. Shift in $^{13}C/^{12}C$ and inferred change in Gulf of Alaska (GOA) vs. Prince William Sound (PWS) carbon dependency (see Kline 1998b, for explanation of delta notation and method of data interpretation) of juvenile herring and pollock in 1994 - 6 (from Kline 1998a). The distribution of values are shown as box and whisker plots that denote the 10th, 25th, 50th, 75th, and 90th percentiles; ouliers are shown as symbols. There was a large shift to greater GOA carbon dependency in 1995 for both species as indicated by the large change between the Fall of 1994 and the Fall of 1995.

The Ecopath modeling group (Pauly and Pimm et al.) Trustee Council sponsored synthesis of known ecological relationships of many of the organisms inhabiting PWS will be used to conduct perturbation experiments to examine EVOS and restoration effects. The utility of this effort will in part be dependent on how realistic their models are. One way to determine if the model is realistic is to compare model predictions with those made using an independent method. Ecopath generates as part of the output, the fractional trophic level for each functional group defined in the model input that can be validated with $^{15}N/^{14}N$ data (Kline and Pauly 1998). Kline and Pauly (1998) validated a preliminary PWS Ecopath model using this novel approach. They used a limited number of functional groups (Fig. 3) which contrasts with the full Ecopath model which will have ~ 50. In comparison to the preliminary model, the artifact of functional group over-aggregation will be significantly reduced in the full model, enabling a more robust Ecopath validation if $^{15}N/^{14}N$ data for a large proportion of the functional groups were available.

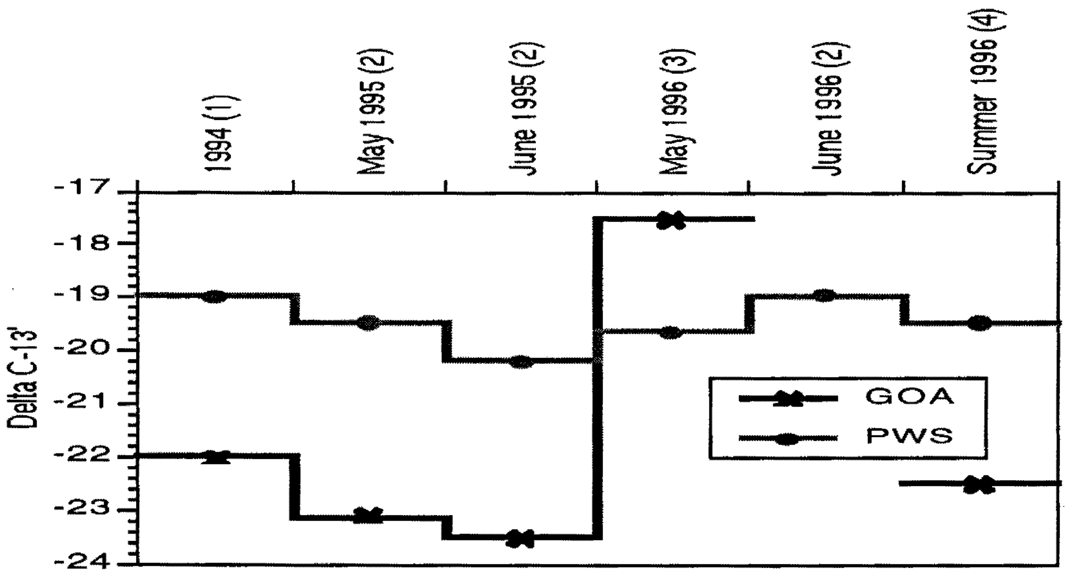

Figure 2. Time series of $^{13}C/^{12}C$ measured in feeding *Neocalanus cristatus* from Prince William Sound (PWS) and the Gulf of Alaska (GOA). Points reflect mean values, standard deviations were 0.5 to 1 delta units. PWS and GOA values were consistently statistically different (Kline 1998a, 1998b).

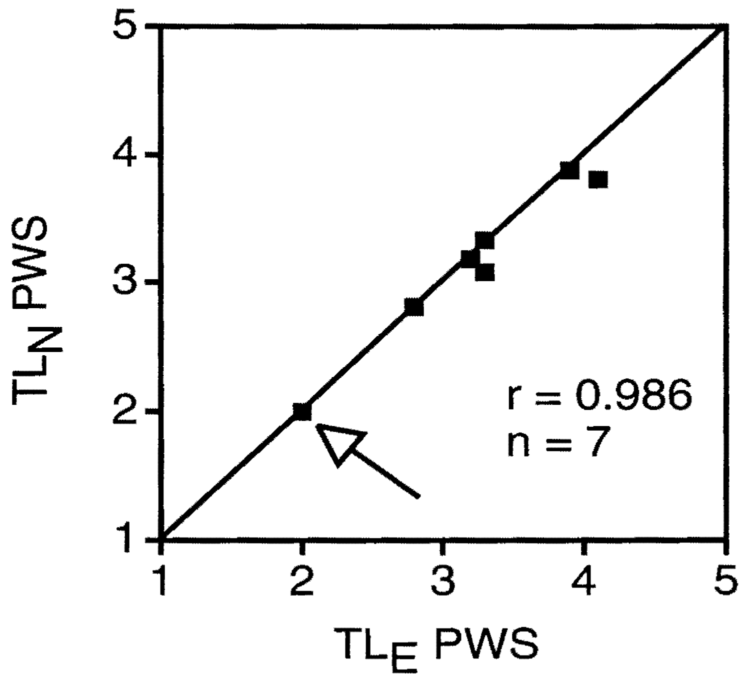

Figure 3. An example of using trophic level determined by $^{15}N/^{14}N$ content (TL_NPWS) to validate trophic level predicted by Ecopath modeling (TL_EPWS). The Arrow indicates the calibration point, remaining points are the estimated trophic level values for six Ecopath functional groups. From Kline and Pauly (1998).

NEED FOR THE PROJECT

A. Statement of Problem

The Problem: Recovery of EVOS damaged species is uncertain in light of regime shifts

Decadal-scale changes in the production cycles of the subarctic Pacific Ocean have been conjectured to effect population changes in fishes and their zooplankton forage base (Brodeur and Ware 1992, Francis and Hare 1994). A "ring of zooplankton" occurring near the Gulf of Alaska (GOA) continental shelf break appears to undergo dramatic oscillations in abundance over decadal time scales (Brodeur and Ware 1992). This "ring of zooplankton" is driven onto the shelf providing the ecosystem with an important forage base (Cooney 1988, 1993). Natural stable isotope (NSI) data suggested that the transport of zooplankton from the GOA into Prince William Sound (PWS) may provide significant quantities of forage for food webs and may be a good method for detecting changes in biophysical coupling in the PWS region (Kline 1998b).

A recent "regime shift" similar to that seen in the past (Brodeur and Ware 1992, Francis and Hare 1994) is conjectured to be presently occurring in the North Pacific (Anderson et al. 1996). Post-EVOS recoveries are uncertain since the regime shift may impede population increases. Recently, using NSI, it has been possible to ascertain that GOA primary productivity patterns vary at interannual time scales and that GOA production is important to PWS (Kline 1998b). Using retrospective NSI analysis, it may be possible to assess whether fluctuations in primary production took place since EVOS. If so, this could explain the poor recovery of some injured species. Furthermore, fluctuations in the mass balance of carbon postulated to be taking place can be incorporated into applications of the Ecopath model being developed by Trustee Council funding which can also be validated using NSI data (Kline and Pauly 1998).

<u>Need #1: Gulf of Alaska productivity fluctuations - retrospective analysis since EVOS</u>

There is a discontinuity between the start of PWS ecosystem studies in 1994 and the timing of EVOS in 1979. Ecosystem shifts occurring in the GOA since 1989 were thus not incorporated in present studies. To overcome this perspective, retrospective NSI analyses may enable a reconstruction systematic ecological changes occurring since 1989.A retrospective approach is being used by GLOBEC in several projects in the N.E. Pacific as a means of overcoming temporal limitations in our database (U.S. GLOBEC 1996). Fixed tissues such as the protein layer on the exterior of mussels provide a recent record of changes in the isotopic composition of their phytoplankton diet. An opportunistic collection of *Mytilus californianus* from Middleton Island made in September 1997 provides an inexpensive approach to retrospective analysis. Middleton Island's location in the Alaska Current provides an "upstream perspective" on the EVOS area since samples from there will reflect changes in plankton upstream before interaction with PWS-origin carbon is possible.

Need #2: Mass-balance modeling validation data gaps

Kline and Pauly (1998) established the utility of using NSI data to validate the Ecopath mass-balance model (Project 330). This was done with a small number of highly aggregated functional groups. The final model will likely have about 40-50 functional groups (Table 1). Of the functional groups listed good isotopic representation is currently available for about 7 (Table 1). Thus confident model validation could only be performed for a limited selection of the functional groups. Additional samples for 17 functional groups are available as archived or stored samples (underlined yes in the column labeled "sample availability") while another 14 functional groups (underlined yes in the column labeled "sample accessibility") could be easily sampled. A total of ~ 40 functional groups providing a good model validation could be made available by augmenting the existing database by analysis of existing samples and additional sampling (Table 1).

Table 1. Ecopath model functional groups as of April 1998 and potential isotopic model validation data (groups 25, 26, and 27 are likely to be dropped from the model. Uncertain functional group size break criteria at time of this writing reflected by question marks. Data courtesy of T. Oakey, Univ. British Columbia.

Functional group	Species	Data availability	Sample availability	Sample accessibility	Final data avail probability
1 Resident Orcas	orca	none	no	no	poor
2 Sm cetaceans	porpoise	none	no	no	poor
3 Adult Herring	herring >?	good	yes	yes	good
4 Juv. Herring	herring < ?	good	yes	yes	good
5 Baleen Whales	humpback	none	no	no	poor
6 Nearshore Pelagics	Juv tom and p cod	fair	no	yes	good
7 Offsh Sm Pelagics	other osmerids, lanternfish, smoothtongue	fair	yes	yes	good
8 Offsh Lg Pelagics	sharks, pel RFs, gadids	fair	yes	yes	good
9 Capelin	capelin	fair	yes	yes	good
10 Sandlance	sandlance	fair	no	yes	good
11 Squid	squid	fair	yes	yes	good
12 Sea otter	sea otter	none	no	no	poor
13 Arrowtooth Adult	arrowtooth fldr >?	poor	yes	yes	good
14 Arrowtooth juv	arrowtooth fldr <?	none	no	yes	good
15 Pollock 3+ age	3+age pollock	good	yes	yes	good

16 Pollock 0 age	0 age pollock	good	yes	yes	good
17 Pollock 1-3 age	1-3 age pollock	fair	yes	yes	good
18 Nearshore Demersal	greenlings, sculpins, gunnels, shanny, ronquils	fair	yes	yes	good
19 Shallow Lg Epibenth.	seastars, crabs	none	yes	yes	good
20 Shallow Sm Epibenth.	mussels, periwinkles, barnacles, limpets, chitons, amphipods, other snails	none	no	yes	good
21 Shallow Lg Infauna	polychaetes	none	no	yes	good
22 Shallow Sm Infauna	clams	none	no	yes	good
23 Mid. Sm Epibenth.	ophioroids	none	no	yes	good
24 Mid Lg Epibenth.	sea pens, crabs	none	yes	yes	good
25 Mid Lg Infauna					
26 Mid Sm. infauna					
27 Deep Sm Infauna					
28 Omniv.-zooplankton	euphausiids, amphipods, larval Fishes, chaetognaths, decapods	fair	yes	yes	good
29 Herb.-zooplankton	copepods, larvaceans, pteropods	good	yes	yes	good
30 Diatoms	diatoms (See McRoy)	fair	yes	yes	good
31 Flagellates	flagellates (See McRoy)	fair	yes	yes	good
32 Macroalgae	kelps, eelgrass	none	yes	yes	good
33 Fish-eating birds	kittiwakes (See Suryam)	fair	yes	yes	good
34 Invert.-eating Bird	(See Bishop)	poor	no	no	good
35 Avian Raptors	eagles	none	no	no	poor
36 Transient Orcas	orca	none	no	no	poor
37 Adult Salmon	salmonidae adult	fair	no	yes	good
38 Pinnipeds	seals, sealions (See Schell)	good	yes	yes	good
39 Salmon Fry 0-6 cm	5 *Oncorhynchus* sp <6cm	fair	yes	yes	good
40 Salmon fry 6-12 cm	5 *Oncorhynchus* sp >6cm	fair	yes	yes	good
41 Meiofauna	infauna < 1mm	none	no	yes	good
42 InshoreDetritus	<20 m(macro alg)	none	no	yes	good
43 Offshr Detritus	>20m (plankton)	none	no	yes	good
44 Rockfishes	*Sebastes* spp.	fair	yes	yes	good
45 Sablefish	sablefish	none	yes	yes	good
46 Lingcod	lingcod	none	yes	yes	good
47 Halibut	halibut	poor	yes	yes	good

48 Herring eggs	herring eggs	none	no	yes	good
49 River otters and minks	(see Ben-David)	good	yes	yes	good
50 Carnivorous jellies	ctenophores, cnidarians	none	yes	yes	good

Urgency and scheduling of analysis in relation to expected delivery of the Ecopath model

There will be a significant time lag from date when funding begins to when data will be available for model validation. First, samples will need to be prepared in the laboratory, converting them into a finely-powdered form. Second, samples will be sent out for mass spectrometry at the University of Alaska Stable Isotope Facility. It takes 6 to 9 months to get NSI data back. Therefore, data are not likely to be available until about a year from start date. Therefore it is imperative that this project commence in the forthcoming fiscal year. To expedite the process, NSI studies will focus on samples already available (yes in the "Sample availability" column in Table 1) in FY99 while FY00 will be used to additional samples accessible through other projects.

B. Rationale/Link to Restoration

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

C. Location

Prince William Sound

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Community involvement and traditional ecological knowledge was incorporated into the sampling. For example, local fishermen provide the P.I. with the knowledge and opportunity to acquire the *Mytilus californianus* samples.

PROJECT DESIGN

Natural stable isotope abundances reflect (1) trophic level and (2) source of assimilated matter and are thus a proxy for the change in diet. Stable isotope ratios will thus be used as a indicator of production and shifts in predation as tests of hypotheses which are stated below in relation to the stated needs.

A. Hypothesis-based Objectives

The needs described above suggest several hypotheses, listed below, that form the basis for the project objectives.

<u>For Need #1 -- thus Objective #1</u>
$Ho_{1.1}$: The isotopic shift seen in 1995 was a singular anomaly, therefore the GOA $^{13}C/^{12}C$ values in earlier years will be consistent.
$Ha_{1.1}$: If they are different, what is the pattern (if there is one)?
$Ho_{1.2}$: The $^{13}C/^{12}C$ of *Mytilus californianus* = $^{13}C/^{12}C$ of *Neocalanus.* This is expected since both are herbivores.
$Ha_{1.2}$: If they are not equal is the there a systematic difference?

There are three goals to be fulfilled for Objective #2:

1. Reconstruct a $^{13}C/^{12}C$ time-series covering at least the 1989 - 1997 period.

2. Compare the time-series with observed $^{13}C/^{12}C$ changes in 1994-1997 (Fig. 2 plus the additional data-year (1997) currently being generated in project 311).

3. Publication of the results in the open literature.

<u>For Need #2 -- thus Objective #2</u>
$Ho_{2.1}$: Trophic level of each functional group predicted by Ecopath = the trophic level of each functional group predicted by their mean $^{15}N/^{14}N$.
$Ho_{2.2}$: Omnivory index of each functional group predicted by Ecopath = the standard deviation of trophic level of each functional group predicted by individual $^{15}N/^{14}N$ values.

There are three goals to be fulfilled for Objective #2:

1. Provide a better representation of the Ecopath functional groups so as to enhance model validation. Note that only a limited number of functional groups were used in the preliminary model validation (Fig. 3). The goal is to make a substantial improvement.

2. Provide validation data for the more model-sensitive higher trophic levels (D. Pauly, pers. comm.). Much of the predictive power of the Ecopath model is for trophic level 4 and 5 functional groups, therefore validation of these functional groups would provide a robust test of the model.

3. Publication of the PWS Ecopath model validation in the open literature, this would have to be a significant leap over Kline and Pauly (1998) to pass the reviewers, hence goals 1 and 2.

See Kline and Pauly 1998 (embedded within Kline 1998b) for a description of the validation method.

Data Gaps

The proposed study will build upon the existing data base; adding new data will fill data gaps and further the construction and tests of conceptual food webs supporting productivity in the greater Prince William Sound area. The goal is to determine the trophic positions and to define the natural history parameters accessible from NSI data in light of the observed declines in their populations. These include changes in trophic level over the lives of pelagic organisms, habitat dependencies, seasonal energetics and trophic dynamics relative to other community organisms. As part of this goal, we will integrate our analytical work with the field and laboratory studies of other investigators looking at food web structure, productivity of lower trophic levels, and provide validation data for assessment of conceptual and quantitative models.

Sampling objectives are listed in relation to needs and their hypotheses. The emphasis will shift among the objectives by fiscal year (these are given proceeding each objective).

B. Objective-based Methods

For Objective 1, Retrospective Analysis Of GOA Production Shifts Since EVOS

FY99-00: Stable isotopic analysis of the outer protein layer (periostracum) on the shells and body tissues of Sea-mussels (*Mytilus californianus*) of varying ages collected at Middleton Island (N= 50 mussels) in September 1997. The periostracum will be analyzed by cutting sections (of 2.0 mg for each analysis) along annular growth rings. Mussels of different age will be used to extract data from various years (as annuli are wider and more distinct at earlier ages) to reconstruct an isotopic time series retracing conditions from 1997 backwards in time to EVOS and earlier. For example a 5 to 10 - year old mussel will resolve well recent years whereas a 10 to-20 year old will resolve years when the mussel was younger. Overlapping years (of periostracum samples) of good age resolution will be used to inter-calibrate mussels while younger mussels will be calibrated against our zooplankton database (Fig. 2). An estimated 250 isotopic analyses (~ n = 10/ mussel) will be required for this task in FY99 (*reduced from 500 in original DPD*). The expected results would consist of an isotopic characterization in GOA isotopic signature from 1989 (possibly earlier) to 1997. The following question will be asked: Did changes of the magnitude seen in 1996 occur in other years? If so, how often. If not, then the 1996 will be considered an anomaly rather than a common occurrence.

<u>For Objective 2, Addressing Ecopath Model Validation Data Gaps</u>

FY 99-00: A) Analysis of available samples from the P.I.'s archives and samples from other P.I.'s.

The purpose of this objective is to acquire data most cost-effectively - without additional field sampling. Functional groups identified for additional analyses are noted by the underlined <u>yes</u> in Table 1. Those underlined in the column "sample availability" are planned for analysis in FY99. Since the Ecopath model is centered on data collected from 1994-6 and for which years these samples are from, they are optimal for this purpose. An estimated 550 isotopic analyses will be required for this task in FY99 (*reduced from 750 in original DPD*).

FY00-01 B) Collection and analysis of additional samples as needed.
Once sample archive sources are exhausted, additional selective sampling will be made. Those functional groups with <u>yes</u> underlined in Table 1 under the column "sample accessibility" will require this supplemental sampling in FY00. An estimated 600 isotopic analyses will be required for this task in FY00.

The methods for calculating trophic level and omnivory index are given in Kline and Pauly 1998 (duplicated in Kline 1998b). The data generated will used in a similar way.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

N/A

SCHEDULE

This schedule has been updated over the 1998 DPD to reflect the actual project 393 commencement day of 1 Aprill 1999. See also attached timeline.

A. MEASURABLE PROJECT TASKS for FY00 (October 1, 1999 - September 30, 2000)

Oct. 99 - Jun. 00:	Preparation of archived samples (for Objectives 1 & 2) for mass spectrometry
Oct. 99 - Sep. 00:	Mass spectrometry at UAF (~ 6-9 month processing time)
Dec. 99 - Sep. 00:	Process new isotope data

B. Project Milestones and Endpoints

Apr. 1999 - Jun. 2000:	Preparation of archived samples for mass spectrometry
Jul. 2000 - Jan. 2001:	Acquisition and preparation of new samples for mass spectrometry
Jan. 2000, 2001, 2002:	Attend Annual Restoration Workshop
Dec. 1999 - Dec. 2001:	Process new isotope data
Apr. 2000 - Dec. 2002;	Data, receipt (from mass spect lab), integration and synthesis
Oct. 1999 - Dec. 2002:	Preparation for and dissemination of results at EVOS and other Symposia
Jan. - Apr. 2000, 2001:	Preparation of Annual Reports
Jan. - Apr. 2002:	Draft final report preparation
Sept. 30 2002:	Final Report revisions

C. Completion Date

September 2002 (Final Report)

PUBLICATIONS AND REPORTS

Kline and Pauly - a greatly augmented sequel to Kline and Pauly (1998) incorporating validation of the model developed in project 330) but is planned for FY01-02.

Kline - A paper based on the retrospective analysis is planned for FY01.

PROFESSIONAL CONFERENCES

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

NORMAL AGENCY MANAGEMENT

N/A

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Collaboration with other EVOS investigators will continue and facilitate relating carbon-source dependency with e.g., somatic energy content (A.J. Paul) and trophic level (D. Pauly and S. Pimm). Other P.I.'s in possession of NSI data for certain functional groups, noted in Table 1 (their names proceeded by "see") will be asked to provide appropriate portions of pertinent data for incorporation into objective #2. Results of analyses will be exchanged at workshops and by telecommunications. Preliminary analysis from the integrated effort will be used to direct retrospective analysis of archived samples. Sampling will be coordinated with other P.I.'s and within the auspices of other biota sampling programs. Pertinent data of each sample (i.e. data on each individual fish will be shared among components). Coordination in relation to specific objectives listed in project design section.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

Since approval of funding was delayed until until December 1998 and the contract was not completed until 1 April 199, the project schedule has been reset in time accordingly. It is still planned as a three-year project. See attached Timeline for details.

PROPOSED PRINCIPAL INVESTIGATOR

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Project 393 Schedule

	Old (rev. DPD)		**Actual**		Ecopath workshop	Prepare archived samples (obj 1 & 2) for mass spect	Acquisition and Preparation of new samples for mass spect	Mass spectrometry at UAF (6-9 month process. time)	Process new isotope data	Data Synthesis	EVOS-TC Workshop	Prep Annual Report	Final Report
FY	C-year	month	**C-year**	**month**									
1999	1998	Oct	**1999**	**Apr**	Oct 98	Start							
1999	1998	Nov	**1999**	**May**		*							
1999	1998	Dec	**1999**	**Jun**		*							
1999	1999	Jan	**1999**	**Jul**		*		Start					
1999	1999	Feb	**1999**	**Aug**		*		*					
1999	1999	Mar	**1999**	**Sep**		*		*					
1999	1999	Apr	**1999**	**Oct**		*		*					
1999	1999	May	**1999**	**Nov**		*		*					
1999	1999	Jun	**1999**	**Dec**		*		*	Start				
1999	1999	Jul	**1999**	**Jan**		*		*	*		*		
1999	1999	Aug	**2000**	**Feb**		*		*	*			Start	
1999	1999	Sep	**2000**	**Mar**		*		*	*			*	
2000	1999	Oct	**2000**	**Apr**		*		*	*	Start		*	
2000	1999	Nov	**2000**	**May**		*		*	*	*		Complete	
2000	1999	Dec	**2000**	**Jun**		Complete		*	*	*			
2000	2000	Jan	**2000**	**Jul**			Start	*	*	*			
2000	2000	Feb	**2000**	**Aug**			*	*	*	*			
2000	2000	Mar	**2000**	**Sep**			*	*	*	*			
2000	2000	Apr	**2000**	**Oct**			*	*	*	*			
2000	2000	May	**2000**	**Nov**			*	*	*	*			
2000	2000	Jun	**2000**	**Dec**			*	*	*	*			
2000	2000	Jul	**2000**	**Jan**			Complete	*	*	*	*		
2000	2000	Aug	**2001**	**Feb**				*	*	*		Start	
2000	2000	Sep	**2001**	**Mar**				*	*	*		*	
2001	2000	Oct	**2001**	**Apr**				*	*	*		*	
2001	2000	Nov	**2001**	**May**				*	*	*		Complete	
2001	2000	Dec	**2001**	**Jun**				*	*	*			
2001	2001	Jan	**2001**	**Jul**				*	*	*			
2001	2001	Feb	**2001**	**Aug**				*	*	*			
2001	2001	Mar	**2001**	**Sep**				*	*	*			
2001	2001	Apr	**2001**	**Oct**				Complete	*	*			
2001	2001	May	**2001**	**Nov**					*	*			
2001	2001	Jun	**2001**	**Dec**					Complete	*			
2001	2001	Jul	**2001**	**Jan**						Complete	*		Start
2001	2001	Aug	**2002**	**Feb**									*
2001	2001	Sep	**2002**	**Mar**									*
2001	2001	Oct	**2002**	**Sept**									Draft
2001	2001	Dec	**2002**	**Dec**									Final

Supplement to Project 00393DPD

A. Response to Chief Scientist's queries

1. Testing feasibility of using mussels for retrospective assessment of isotopic trends.

Sampling has just gotten underway as the 0.1 mg resolution balance ordered for this project was only delivered on 16 June. It was ordered subsequent to commencement of the project on 1 April 1999 (project started late since funding was not approved until December 1998 and NOAA contracting was not completed until 1 April 1999, only 15 days before the second year DPD was due!) and had been on back-order with VWR.

The first task is to determine the proper sample size, e.g., X.X mg, for mass spectrometry (underway). The periostracum samples consist nearly of pure protein, therefore optimal sample size for mass may be different than typical animal tissues samples that contain lipids. Testing involves running samples of various sizes through the mass spectrometer and assessing the ion currents produced. 16 samples consisting of 4 each of 4 mass sizes (~ 0.5, 1.0, 1.5, and 2.0 mg) are being analyzed. Resultant ion current measurements will be plotted versus sample mass (independent variable or X axis) using scatterplots for $\delta^{13}C$ and $\delta^{15}N$. The mean value of the mass needed to produce optimal ion currents will be determined from the plots and used for subsequent work.

The second task will consist of a series of a few (N ~ 12) annuli samples from an individual mussel. Data from these samples will be plotted (scatterplots as above but with annuli and shell distance (along long axis of shell from which periostracun was sampled) as independent variables) to assess inter-annual variability for comparisons with our zooplankton data. These data will demonstrate the usefulness of the technique.

We are requesting that the test samples be expedited i.e., run quicker than the normal 9-month turnaround time from the UAF mass spec lab. The small samples sizes of these two initial tasks enables expediting of the mass spectrometric analysis. We expect to have results for these tasks by the end of the summer at which point the full analysis can go forth.

2. Commitment of UBC Ecopath collaborators

Daniel Pauly and Tom Okey appear to be fully committed to Ecopath. They are presently working on two manuscripts, our preliminary validation data will be used for the more appropriate one. We are planning on an advanced validation paper to be written late in 2001 which will be subsequent to acquisition of project 393 data and will include Ecopath functional groups not represented with presently available data.

Note reprints of Kline and Pauly 1998 are now available, e-mail Kline if a separate copy is desired.

Citation: Kline, Thomas C., Jr. and Daniel Pauly 1998. Cross-validation of trophic level estimates from a mass-balance model of Prince William Sound using $^{15}N/^{14}N$ data. *In*: Funk, F., T.J. Quinn II, J. Heifetz, J.N. Ianelli, J.E. Powers, J.F. Schweigert, P.J. Sullivan, and C.-I. Zhang (eds.), Fishery Stock Assessment Models. Alaska Sea Grant College Program Report No. AK-SG-98-01. University of Alaska Fairbanks, pp. 693-702.

This e-mail message is included to provide an indication of interest by Pauly et al.:

From: pauly@fisheries.com
Date: Sat, 19 Jun 1999 15:12:14 -0500
Subject: RE: our Wakefield paper
To: tkline@grizzly.pwssc.gen.ak.us

Tom, (and Tom) I have received the 'reprints' and the books as well, and I am quite pleased with the whole thing. My thanks to you for the fruitful collaboration.
Yes, there are plans to publish a paper on the PWS model. This paper may be a good place to put a graph comparing a few of our (presently available) trophic level estimates, and hence satisfying those that would question their estimation. This would also make you a co-author of said paper. I am copying this message to Tom Okey, with whom you should follow up on this (he will be the first author).
I am also looking forward to the new estimates of trophic levels and hence to the new paper we can do.
Best regards
Daniel

to: INT:tkline@pwssc.gen.ak.us
cc: tokey

Tom Okey follow-up:

From: tokey@fisheries.com
Date: Mon, 21 Jun 1999 12:39:46 -0500
Subject: RE: our Wakefield paper
To: tkline@grizzly.pwssc.gen.ak.us

Hi Tom, There actually seem to be two papers coming out of the PWS block, one on a rather specific cascading mechanism with Sea otters and soft bottoms, and the other with simulations of earthquakes and oil spills. At the moment, I have most of the description of the model in the sea otter one, but I might switch that around and try to publish the oil spill one first including a good description of the model--that might be a good one for some validation data. As you may gather, there are changes in thinking and organization happening. I'll keep you appraised.
Thanks,
-Tom

Progress on Ecopath validation part of 00393 includes assembly of a sample inventory that is being used for sample selection. Samples have been selected and are being prepared for sample analysis. The initial batches of samples have already been sent to the UAF stable isotope facility.

B. Further budget justifications - 00393 budget review
(item numbers are consistent with those in review)

4. Salary variations: Average monthly costs = total of salary and benefits/ months. The principal source of variation is the number of anticipated field days which have a higher benefit rate because of added insurance. Note: the worksheet attached to DPD following budget forms is provided for further clarification. Salary increases occur(ed) each year usually in April while changes in benefit rates occur(ed) at anniversary of PWSSC employment and with change in number dependents.
7. Annual workshop is now only budgeted in 00393
8 Conference is now budgeted in 00393. EVOS workshop travel includes 1/2 day of travel to and 1/2 day of travel from workshop to PI homebase for which per diem is due. The PWSSC follows Federal travel procedures and rates, refer to Penelope Oswalt, PWSSC financial officer for additional details.
9. Full day of travel to and full day of travel from 5-day-long meeting (typical length for national meeting such as ASLO) is budgeted for. The PWSSC follows Federal travel procedures and rates, refer to Penelope Oswalt, PWSSC financial officer for additional details.
10. deleted
12. Computer justification: P.I.'s computer dates from 1995 and is basically obsolete, memory (32 mb) and speed (120 MHz) are not up to even the cheapest current models. Software incompatibilities have been problematic for collaboration, updates not possible with old machine. There have also been hardware problems - disk drive malfunctions and system crashes due to part failures from aging. EVOS not willing to pay for computer equipment lease (rejected in previous budget review), must therefore buy hardware instead.
13. Indirect costs: Shipping costs are need for secured shipping samples to and from Fairbanks. Presentation costs include printing of poster for EVOS workshop. Office supplies, photocopies are directly charged to specific projects and are documented (refer to Penelope Oswalt, PWSSC financial officer for additional details).

Revise 7-14-99
Approved rc 8-9-99

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

Budget Category:	Authorized *FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$143,663.3						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$116.8K	$143,663.3			Estimated *FY 2001	Estimated FY 2002		
General Administration	$8.2K	$10,056.4						
Project Total	$125K	$153,719.7			$127.7			
Full-time Equivalents (FTE)		1.2						
	*Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:
General Administration formula altered so as to generate correct value, i.e., 7%

FY00

Prepared:

Project Number: 00393
Project Title:Prince William Sound Food Webs: Structure and Change, Submiited Under the BAA
Agency: NOAA

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		$87,580.6						
Travel		$3,680.0						
Contractual		$19,070.0						
Commodities		$2,500.0						
Equipment		$2,100.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$116.8K	$114,930.6			Estimated FY 2001	Estimated FY 2002		
Indirect	$8.2K	$28,732.7						
Project Total	$125K	$143,663.3			$127.7			
Full-time Equivalents (FTE)		1.2						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments: FY 2001 is based upon a 25% IDC (earlier DPD was 20%)

FY00

Project Number: 00393
Project Title: Prince William Sound Food Webs: Structure and Change, Submiited Under the BAA
Name: Prince William Sound Science Center

FORM 4A
Non-Trustee
SUMMARY

ared:

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
T. Kline	Principal Investigator		6.0	8618.9		51,713.4
J. Williams	Technician		4.0	5587.6		22,350.4
TBN	Technician		4.0	3379.2		13,516.8
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		14.0	17585.7	0.0	
					Personnel Total	$87,580.6

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
National meeting	800.0	1	7	132.0	1,724.0
registration and car rental	250.0	1	5	50.0	500.0
EVOS and collaborative workshops	200.0	2	6	151.0	1,306.0
car rental	0.0	0	3	50.0	150.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$3,680.0

FY00

Prepared:

Project Number: 00393
Project Title:Prince William Sound Food Webs: Structure and Change, Submiited Under the BAA
Name: Prince William Sound Science Center

FORM 4B
Personnel
& Travel
DETAIL

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

Contractual Costs:				Proposed
Description			cost per unit	FY 2000
PWSSC network charge by computer-months	computer months	11	100	1,100.0
Stable Isotope Analysis	number:	569	27	15,363.0
Freeze drier charge	number:	569	3	1,707.0
photocopying				200.0
shipping				300.0
communications (fax and phone)				400.0
			Contractual Total	$19,070.0

Commodities Costs:	Proposed
Description	FY 2000
Lab supplies miscl	750.0
Lab supplies: chemicals, vials, knives	750.0
Office supplies miscl	400.0
Computer supplies and upgrades	400.0
Dyesub, photog. (presentation materials)	200.0
Commodities Total	$2,500.0

FY00

ared:

Project Number: 00393
Project Title: Prince William Sound Food Webs: Structure and Change, Submiited Under the BAA
Name: Prince William Sound Science Center

FORM 4B
Contractual &
Commodities
DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2000
60% of a Computer per e-mail to Sandra Schubert on 14 July 1999	0.60	3500.0	2,100.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$2,100.0

Existing Equipment Usage: Description	Number of Units	

FY00

Prepared:

Project Number: 00393
Project Title: Prince William Sound Food Webs: Structure and Change, Submiited Under the BAA
Name: Prince William Sound Science Center

FORM 4B
Equipment
DETAIL

Approved TC 8-9-99

Assessment of Spot Shrimp Abundance in Prince William Sound

Project Number:	00401
Restoration Category:	General Restoration
Proposer:	C. Hughey/ Valdez Native Tribe, C. O'Clair/ NOAA
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	Cont'd
Duration:	2nd yr. 4 yr. project
Cost FY 00:	$88.7
Cost FY 01:	$95.0
Cost FY 02:	$33.0
Geographic Area:	Prince William Sound
Injured Resource/Service:	Spot shrimp, subsistence

ABSTRACT

This project will estimate the abundance of spot shrimp and determine the structure of the spot shrimp population in western Prince William Sound. The project will augment current Alaska Department of Fish and Game surveys to determine whether the spot shrimp population is recovering from depletion. To maintain consistency with the timing of Alaska Department of Fish and Game surveys, the first full sampling cruise will take place in October 1999. In year one, western Prince William Sound will be surveyed for study sites. In years two and three, spot shrimp relative abundance, population structure and reproductive potential will be estimated at the study sites. An added objective in year three will be an estimate of recruitment potential achieved by expanding the depth range of the sampling into shallow water to assess the relative abundance of juveniles. Year four will be closeout, production of manuscripts, and providing input into the development of a shrimp management plan with the Alaska Department of Fish and Game.

A. INTRODUCTION

Most crustacean stocks in Alaska are in need of rebuilding. Evidence that the rapid expansion of crab and shrimp fisheries in Alaska from 1960 to 1980 resulted in the serial depletion of these stocks is compelling (Orensanz et al. 1998). The effects on recruitment of climatic change, including climate-mediated increases in predation or disease, as opposed to overfishing, probably played an important role in the decline of many crustacean stocks in Alaska (Orensanz et al. 1998). The case for overfishing as the main cause for population decline is perhaps strongest for spot shrimp, *Pandalus platyceros* Brandt, in Prince William Sound (Trowbridge 1994, Orensanz et al. 1998).

The commercial spot shrimp fishery in Prince William Sound (PWS) began in the 1950's and remained small until the late 1970's. After 1975 the fishery expanded rapidly. The harvest increased from 7 tonnes in 1978 to more than 131 tonnes in 1986 as the number of vessels participating in the fishery increased ninefold to 80 vessels (Trowbridge 1994). Area closures after the *Exxon Valdez* oil spill resulted in a precipitous decline in the harvest in 1989. Low stock abundance necessitated closure of the fishery in 1990 by emergency order (Orensanz et al. 1998). A reduced fishery involving 15 vessels took place in the fall of 1991, but the season was closed early when a reduced guideline harvest level was reached. Catch per unit effort (CPUE) averaged 0.4 kg of whole shrimp per pot during the 1991 season. The fishery was closed in 1992 and remains closed (Trowbridge 1994, Orensanz et al. 1998). The decision point for reopening the fishery has been set tentatively at a survey CPUE of 0.6 kg/pot (Trowbridge 1994).

Annual surveys of the abundance of spot shrimp in PWS begun in 1989 by the Alaska Department of Fish and Game (ADF&G) continue to the present. The surveys sample spot shrimp at six to eight sites in the seven major statistical reporting areas that divide the Traditional Harvest Area in western PWS (Trowbridge 1992, 1994). From 1989 to 1993 the survey CPUE has declined from 0.6 kg/pot to 0.2 kg/pot. During the same period the percentage of large shrimp (females) increased from 4 to 20% indicating a somewhat reduced recruitment in the near term after 1993 (Trowbridge 1994). This proposal covers year two of the four year study. The study will augment the ADF&G sampling program by adding population information from other areas in PWS, will enhance our understanding of spot shrimp population dynamics by providing information on juvenile distribution, abundance, and size structure, and will ultimately aid ADF&G in developing a management plan for spot shrimp when the population recovers. In FY=99 NMFS personnel took input from the Valdez Native Tribe and former PWS commercial shrimpers to identify potential sampling sites. A preliminary, exploratory cruise will be conducted in August 1999 to evaluate potential sites for the study of spot shrimp population size and structure. The first major cruise of the study will take place in October 1999 to be consistent with the seasonal timing of past ADF&G surveys. The second full year of the study (FY=01) will, in addition to estimating spot shrimp relative abundance, population structure and reproductive potential, determine recruitment potential of the spot shrimp population by expanding the depth range of the sampling into shallow water to assess the relative abundance of juveniles in the population.

NEED FOR PROJECT

A. Statement of Problem

Evidence for depletion of the spot shrimp resource in PWS after 1989 is convincing (Trowbridge 1994). The role that the *Exxon Valdez* oil spill (EVOS) may have played in the reduction of spot shrimp abundance in western Prince William Sound is unclear. Trowbridge (1992) found reduced CPUE in weight and number of spot shrimp in oiled vs unoiled areas in 1989 and 1990 in PWS. The differences in CPUE (number and weight of shrimp) did not persist into 1991. Mean size of shrimp was reduced in the oiled area in all three years. However, Trowbridge (1992) could not find conclusive evidence Athat spot shrimp within PWS were themselves affected by the EVOS@ owing, in large part to limitations in time and funding for spot shrimp damage assessment. Spot shrimp were not considered a high priority species by the EVOS damage assessment process. Lack of pre-spill abundance information coupled with confounding reductions in spot shrimp abundance prior to the spill rendered the species less favorable for a definitive damage assessment study. Trowbridge (1992) ultimately concluded that the observed abundance and structure of the spot shrimp stock in PWS in the first few years after the *Exxon Valdez* oil spill could mostly be explained by fishing pressure. Nevertheless, he hypothesized that highly sensitive shrimp larvae which were probably in the water column and near the surface during the oil spill were adversely affected by oil toxicity. No damage assessment study focused on larvae was initiated after the spill. The impact on the shrimp population after 1989 of exposure to oil of the 1989 year class in the larval stage is unknown.

Of additional concern is the increased pressure on the spot shrimp resource by sport and subsistence shrimpers as a result of greater access to western PWS following the soon to be completed access road connecting Portage and Whittier. Increased cruise ship traffic in and independent tourist visitations to western PWS in recent years may be having adverse impacts on spot shrimp habitat within PWS.

B. Rational/Link to Restoration

This project falls under the category of monitoring. We will seek to assess the extent to which spot shrimp abundance has recovered since the population decline which began just prior to 1989. Although the major cause of the decline was probably overfishing rather than the EVOS, there is great interest by subsistence users of shrimp as well as sport shrimpers and individuals who fished for shrimp commercially in PWS prior to 1992 in the present status of the spot shrimp population in PWS. The ADF&G currently surveys spot shrimp abundance at selected locations in PWS annually. The goal of this study is first to broaden the geographical coverage and increase the amount of replication within existing major statistical reporting areas of the asssessment of spot shrimp abundance in PWS. Second by focusing on the reproductive potential of females and recruitment potential as indicated by the abundance of juveniles in the population we can determine whether the population is recovering. The results of this work should greatly enhance the information base underpinning ADF&G management decisions.

C. Location

This study focuses on various sites in the Traditional Harvest Area for spot shrimp in western Prince William Sound, but will include sites in other parts of the Sound as well. The project will include sites currently surveyed by ADF&G as well as additional sites in statistical reporting areas currently surveyed and in other reporting areas. Elements of the communities of Whittier, Valdez and Cordova that are now or have in the past been associated with the sport, subsistence or commercial harvest of spot shrimp may be affected by the results of the project.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Charles Hughey of Valdez Native Tribe will act as community facilitator for the project. Shrimpers in the Valdez Native Tribe will participate in the project, providing vessels, crew, shrimp pots, buoys, line, etc.

PROJECT DESIGN

Two important considerations enter into the project design. First, the project will overlap as much as possible the existing survey sites of ADF&G as well as add sites, and, to the extent possible, the project will duplicate the methods that ADF&G uses in their surveys. This will accomplish two ends: 1) It will allow us to compare with greater confidence our data with that previously collected by ADF&G on spot shrimp abundance in western PWS in order to determine, more convincingly, whether spot shrimp population recovery is taking place in PWS, and 2) It will be more likely to provide data of the greatest use to ADF&G for future management of the spot shrimp resource in PWS.

The second consideration is that to maximize community involvement and to make the best use of traditional ecological knowledge, shrimpers associated with the Valdez Native Tribe will participate in the project. The shrimpers will, to the extent that they desire, have input into the selection of additional sampling sites and will participate in the sampling. Because the shrimp pots and other fishing equipment used by these shrimpers may differ in configuration from that used by ADF&G, the extent to which the project can overlap the ADF&G sites and sampling dates may permit the calculation of correction factors for comparison of the project=s data with that of ADF&G.

A. Objectives

1. Estimate abundance (CPUE) of spot shrimp by weight and number of individuals (years two and three).

2. Determine the sex and size composition of spot shrimp at the study sites (years two and three).

3. Estimate spot shrimp fecundity and relative number of egg-bearing females at the study sites (years two and three).

4. Estimate juvenile abundance and compare between sites (year three).

5. Compare abundance, sex and size composition, fecundity and proportion of ovigerous females between sites and years (year three).

6. Compare abundance data and data on population structure obtained under the present project with historical data collected by ADF&G to determine if the population is recovering and to assess the potential for full recovery of the spot shrimp population in PWS (year four).

7. Work with ADF&G, using data collected from this study, to develop a spot shrimp management plan for PWS.

B. Methods

The methods that will be used in the proposed study are modified after Trowbridge (1992, 1994). Shrimp pots will be fished at six sites in northern and western PWS previously surveyed by ADF&G (Figure 1). The sampling sites will be located in Unakwik Inlet, at Golden in Port Wells, in lower Culross Passage, in Herring Bay, at northeast Chenega Island and at northern Green Island. Six additional sites, yet to be determined, will be added to the existing ADF&G sites.

At least two strings of shrimp pots will be set at each site. Each string will consist of 11 pots spaced 18.3 m (60 ft) apart along a groundline and buoyed at both ends. Rectangular or circular, stacking pots will be used. Rectangular pots measuring 41 cm x 41 cm x 91 cm (16 in x16 in x 36 in) are used by the ADF&G. The pots are covered with black woven plastic fabric (engineers cloth) except in the two opposing tunnel ends which have a 6.4 cm (2.5 in) tunnel opening set 18 cm (7 in) into each end of the pot. The tunnels are enclosed by 1.3 cm (0.5 in) stretched mesh web. A single 2.4 L perforated plastic jar containing chopped herring is placed in each pot at the time of deployment. If circular pots are ultimately used in this study, the circular pots will be fished along with the ADF&G rectangular design in a side by side comparison to test the relative efficiency of the two pot designs. The pots will be fished in the depth range 37-146 m (20-80 fm) for a minimum of 18 h at each site. In year two additional pot sets will be made in the depth range 0-37 m (0-20 fm) to assess the abundance of juvenile spot shrimp.

Upon retrieval of the pot strings all pandalid shrimp in each pot will be speciated. Spot shrimp will be counted and weighed to the nearest gram on an electronic balance. If time permits, other species of pandalid shrimp (eg. *P. eous* and *P. hypsinotus*) will be counted and weighed. All non-shrimp bycatch will be speciated and counted. All spot shrimp will be sexed and the length of the carapace measured. Additional observations of ovigerous spot shrimp will include egg condition (eyed vs uneyed) and egg color. The egg clutches of a total of 30 ovigerous females will be sampled at each site for estimates of fecundity and the number of dead eggs in the clutch. For nonovigerous females, the presence or absence of breeding dress [characterized by "...the presence of long, simple, and plumose setae on the protopodites of pleopods" (Butler 1980)] will be recorded. Breeding dress indicates a mature female.

A preliminary sampling cruise will be conducted in August 1999 to explore for sites to be added to those currently sampled by ADF&G. Field cruises in the two main years of sampling will be conducted in October (the time of year when ADF&G normally samples) for the purposes of comparing the catch data collected by this project with that previously collected by ADF&G.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

This project will be a partnership between the National Marine Fisheries Service, the Valdez Native Tribe with Charlie Hughey as facilitator and Prince William Sound Economic Development Council.

SCHEDULE

A. Measurable Project Tasks for FY00 (October 1, 1999-September 30, 2000)

October 1 - 31	Sample spot shrimp at ADF&G sampling sites as well as six additional sites.
November 1 - March 31	Process egg samples and analyse data on spot shrimp abundance, sex and size composition, and relative number of egg-bearing females and fecundity of spot shrimp at the study sites in year one.
April 1 - September 30	Respond to reviewers comments on annual report and arrange logistics for sampling cruise in October 2000.

B. Project Milestones and Endpoints

October 15, 1999	Complete sampling for spot shrimp in first full sampling year.
March 31, 2000	Complete estimates of abundance, sex and size composition, and relative number of egg-bearing females and fecundity of spot shrimp at the study sites in year one.

April 15, 2000	Submit annual report (FY00 findings)
October 15, 2000	Complete sampling for spot shrimp in second full sampling year.
February 20, 2001	Complete estimates of abundance, sex and size composition, and relative number of egg-bearing females of spot shrimp at the study sites in year two.
April 15, 2001	Submit annual report (FY01 findings)
June 15, 2001	Complete estimates of spot shrimp fecundity and juvenile abundance at the study sites in year two.
October 31, 2001	Complete comparison of spot shrimp abundance, sex and size composition, fecundity and proportion of ovigerous females between sites and years.
January 15, 2002	Complete comparison of the abundance data and the data on population structure obtained under the project with historical data collected by ADF&G.
April 15, 2002	Submit final report and recommendations to ADF&G for development of a PWS shrimp management plan.

C. Completion Date

September 30, 2002

PUBLICATIONS AND REPORTS

Annual reports will be submitted on 15 April in FY00 and FY01. A final report will be submitted on 15 April in FY02. It is anticipated that at least two publications will derive from this project.

PROFESSIONAL CONFERENCES

Travel funds are requested for attendance of two individuals at the annual Exxon Valdez Restoration Workshop in January 2000.

NORMAL AGENCY MANAGEMENT

The National Marine Fisheries Service (NMFS) does not manage shrimp resources in Alaska and has never been required by statute or regulation to survey spot shrimp populations in PWS. No project similar to the one proposed here has been conducted by NMFS in the past without funds from the Trustee Council. Spot shrimp are managed by ADF&G which conducts annual surveys in PWS to assess the status of the resource.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The Valdez Native Tribe Facilitator Charles Hughey and Prince William Sound Economic Development Council will work with NMFS scientists to successfully complete this spot shrimp project. The ADF&G will be asked to review the proposal and subsequent reports to improve their quality and to increase their relevance to management goals.

The Prince William Sound Economic Development Council has coordinated other projects for EVOS in the past. Recent projects nearing completion are the Chenega Bay Beach Clean-up and the five Oil Waste Management buildings in Valdez, Whittier, Cordova, Chenega Bay and Tatitlek.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

No sampling has been conducted in conjunction with this project yet. Exploratory fishing will take place in August 1999. When sampling is begun circular pots may have to be substituted for the rectangular pots that ADF&G uses. If circular pots are used they will be cross-calibrated with the rectangular pots before full sampling is begun.

PROPOSED PRINCIPAL INVESTIGATORS

Charles E O=Clair
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Auke Bay Laboratory
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Tele: (907) 789-6016, FAX: (907) 789-6094
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Charles Hughey, Valdez Native Tribe
P. O. Box 1108
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FAX: (907) 835-5589

Sue Cogswell, Executive Director
Prince William Sound EDC
P. O. Box 2353
Valdez, AK 99686
Tele: (907) 835-3775, FAX (907) 835-5770
E-mail pwsedc@alaska.net

PRINCIPAL INVESTIGATORS

Charles G. Hughey is a commercial fisherman, EVOS community facilitator for Valdez, and serves on the Alaska Fish and Game Advisory Committee.

Sue Cogswell is executive director of Prince William Sound Economic Development Council and has experience in project management.

Charles E. O=Clair will be responsible for sampling, data analysis and interpretation and report writing. For qualifications see curriculum vitae below.

Mandy Lindeberg. will be responsible for arranging logistics (vessels, equipment, contracts, etc.), will participate in sampling, data processing, and will assist in report writing. For qualifications see curriculum vitae below.

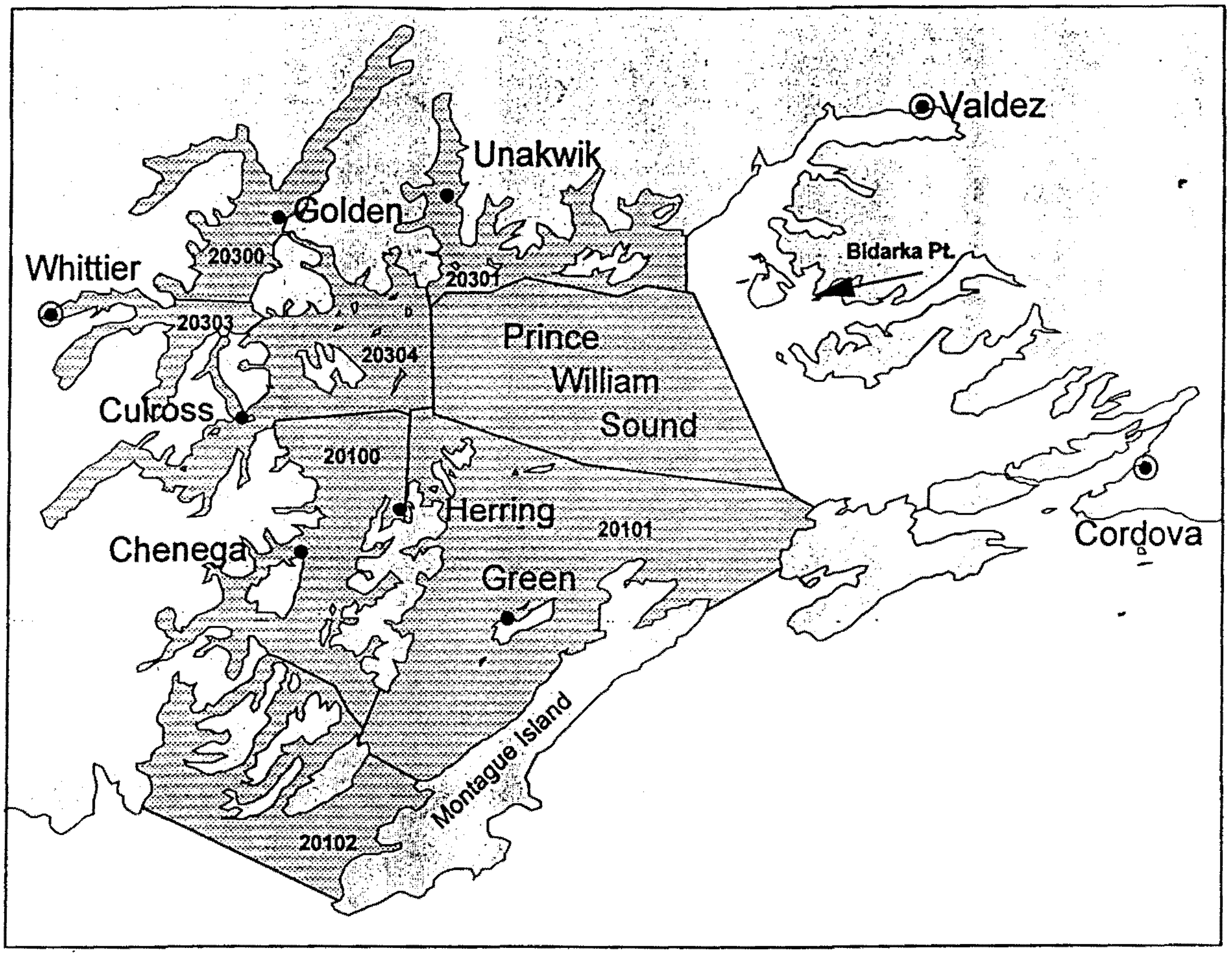

Figure 1. Proposed sampling area (shaded) and core sampling sites (closed circles) for spot shrimp abundance and population structure in western Prince William Sound. Alaska Department of Fish and Game major statistical areas for reporting commercial shellfish catch are outlined within the shaded area. (Major statistical areas are numbered). The Traditional Harvest Area is that area west of a line drawn between Bidarka Pt. and Montague Pt. (Modified after Trowbridge 1992)

Revisi . 7-5-99
approved TC 8-9-99

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
			LONG RANGE FUNDING REQUIREMENTS					
					Estimated FY 2001	Estimated FY 2002		
Personnel	$12,000.0	$40.7						
Travel	$6,600.0	$4.4						
Contractual	$15,000.0	$32.5						
Commodities	$1,800.0	$2.7						
Equipment		$0.0						
Subtotal	$35,400.0	$80.3						
General Administration	$2,900.0	$8.4						
Project Total	$38,300.0	$88.7			$95.0	$33.0		
Full-time Equivalents (FTE)	0.2	0.6						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

Prince William Sound Economic Council will administer the contract with the Valdez Native Tribe who will supply the survey vessel including fuel, Captain, deck hand, gear, and food.

FY00

Prepared: 7/5/99

Project Number: 00401
Project Title: Spot Shrimp - A Population Dynamics Study
Agency: National Oceanic and Atmospheric Administration

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2000 EXXON VALDEZ TRUSTEE 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
O'Clair, C. E.	Fishery Research Biologist	GS-12/10	2.0	8.6		17.2
Lindeberg, M.	Fishery Research Biologist	GS-9/3	5.0	4.7		23.5
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		7.0	13.3	0.0	
					Personnel Total	$40.7

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
JNU/VDZ/JNU	0.6	2	4	0.2	2.0
JNU/ANC/JNU	0.4	2	3	0.2	1.4
VDZ/ANC/VDZ	0.2	2	3	0.2	1.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$4.4

FY00

Project Number: 00401
Project Title: Spot Shrimp - A Population Dynamics Study
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Personnel
& Travel
DETAIL

Prepared: 7/5/99

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

Contractual Costs:	Proposed
Description	FY 2000
Vessel Charter	24.5
Fecundity and egg mortality analysis	8.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$32.5

Commodities Costs:	Proposed
Description	FY 2000
Portable Balance	0.7
Measuring, weighing and laboratorysupplies.	2.0
Commodities Total	$2.7

FY00

Prepared: 7/5/99

Project Number: 00401
Project Title: Spot Shrimp - A Population Dynamics Study
Agency: National Oceanic and Atmospheric Administration

FORM 3B
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
			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

FY00

Project Number: 00401
Project Title: Spot Shrimp - A Population Dynamics Study
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Equipment
DETAIL

Prepared: 7/5/99

00407

Revision 7-26-99
approved TC 8-9-99

Harlequin Duck Population Dynamics and Satellite Telemetry

Project Number:	00407
Restoration Category:	Research
Proposer:	D. Rosenberg/ADFG
Lead Trustee Agency:	ADFG
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	New
Duration:	1st yr. 3 yr. project
Cost FY 00:	$63.8
Cost FY 01:	$71.0
Cost FY 02:	$71.0
Geographic Area:	Prince William Sound
Injured Resource/Service:	Harlequin ducks

ABSTRACT

Harlequin duck populations have not recovered from the effects of the oil spill. Populations are declining in oiled areas of Prince William Sound while increasing in unoiled areas. This project will conduct late-winter boat surveys to assess the recovery of ducks inhabiting oiled areas. Population structure, abundance and recruitment will be compared between oiled and unoiled areas in Prince William Sound to assess trends, population dynamics, and the progress of recovery.

INTRODUCTION

Harlequin duck (*Histrionicus histrionicus*) populations are declining in oiled areas of Prince William Sound (PWS) while they are increasing in unoiled areas (Rosenberg and Petrula 1999). Additionally, harlequin ducks inhabiting oiled areas are at greater risk to hydrocarbon exposure and have lower female survival (overwinter) than ducks in oiled areas (Holland-Bartels, in prep.). In combination, these two studies provide strong evidence that harlequin ducks have not recovered from the effects of the *Exxon Valdez* oil spill (*Exxon Valdez* Oil Spill Trustee Council 1999).

Harlequin ducks occur year-round in intertidal zones of PWS (Isleib and Kessel 1973). At least 1,298 harlequin ducks were estimated to have died as a direct result of oil exposure following the Exxon Valdez oil spill (J. Piatt pers. comm.). Oil spill studies of harlequin ducks in western Prince William Sound (PWS) from 1990-93 found consistently low numbers of birds during the breeding season, little breeding, low productivity, and an apparent decline in post-breeding molting birds (Patten 1995, Patten et al. 1995). In 1995, six years after the Exxon Valdez oil spill there was no sign of recovery (Exxon Valdez Oil Spill Trustee Council 1996).

As a result of the 1990-1993 findings and the lack of recovery, ADF&G initiated population monitoring in 1994 (Rosenberg 1995; Rosenberg et al. 1996; Rosenberg and Petrula 1997; Rosenberg and Petrula 1999). These studies, conducted from 1994 through 1997, found no difference in population structure between oiled and unoiled areas; no brood production in the spill area; and a decline in molting populations. Similar population structures, a positive finding, indicated that the population was in a position to recover. However, the declining trend in numbers during autumn surveys for the oiled areas of western PWS remained a concern, especially since populations in unoiled eastern PWS increased. This indicated that recovery has not occurred.

We believe the lack of brood production in the oiled areas is a function of limited breeding habitat, not oil history. A relatively small percentage of harlequin ducks that winter in PWS also breed in PWS (Rosenberg and Petrula 1999). Ten years after the spill, we do not know where the majority of the PWS wintering population of harlequin ducks breed. We suspect the vast majority breed outside of PWS, likely in interior Alaska or the Yukon Territory, Canada (Rosenberg and Petrula 1999). Therefore, productivity information collected within PWS can not be extrapolated to the larger population and used to assess recovery.

Two other studies have been monitoring the survival and population trends of harlequin ducks in PWS. The decline in the number of harlequin ducks in WPWS that we observed is supported by results from the Nearshore Vertebrate Predator (NVP) project (Holland-Bartels, in prep.). The NVP study indicates a significantly lower ($p<0.10$) survival rate (76.6%) for females wintering in oiled areas than for females wintering in unoiled areas (86.6%). Lower survival rates may be related to the significantly higher ($p<0.01$) EROD (ethoxyresorufin-O-deethylase) enzyme activities (an enzyme indicative of exposure to aromatic hydrocarbons) measured in liver tissues taken from harlequin ducks and Barrow's goldeneyes (*Bucephala islandica*) in oiled areas (Holland-Bartels, in prep.). Harlequin ducks in oiled areas (WPWS) are still being exposed to hydrocarbons, although the effects remain uncertain.

The USFWS marine boat surveys (Agler et al. 1995; Agler and Kendall 1997) have been monitoring marine birds, including harlequin ducks, throughout PWS since 1989. These surveys which were not designed to be species specific, gather information on abundance and distribution only; they have not collected information on population structure. Their findings show harlequin ducks in July remaining relatively stable in oiled areas and increasing in unoiled areas. In March, their surveys show a slight increase in the number of ducks inhabiting oiled sites. This compares with a much greater rate of increase for unoiled areas. Some inconsistency is evident between the ADF&G surveys (Rosenberg and Petrula 1999) and the USFWS surveys (Agler and Kendall 1997). A detailed comparison of the two surveys is presented in Rosenberg and Petrula (1999).

Despite any inconsistencies in survey results, all three studies (Agler and Kendall 1997; Holland-Bartels, in prep.; Rosenberg and Petrula 1999) indicate a divergence between oiled and unoiled populations. Harlequin duck populations in oiled areas (WPWS) are consistently "under-performing" populations in unoiled areas (EPWS). Yet, questions still remain as to the cause of this divergence, and whether survey results primarily reflect lingering effects of the oil spill or extrinsic factors such as local ecology and climate at the breeding, molting, or wintering areas

Sea duck populations, in general, are composed of relatively long-lived birds with delayed sexual maturity. Productivity may be limited to a few favorable years and population levels may change slowly. Long-term population stability depends on high adult survival coupled with a few years of successful reproduction. Initial high losses of adults, especially females, may result in a long and slow recovery period, especially if initial causes of mortality are still influential.

We propose to conduct a winter survey that will compare population trends in the same oiled and unoiled areas surveyed in project \427 (Rosenberg and Petrula 1999). In addition, we propose expanding the geographic coverage of the winter survey to allow us to compare regional differences in population trends within oiled and unoiled areas. Thus, we will compare trends for different geographic regions within oiled and unoiled areas in an attempt to assess geographic effects. We have designed a survey that has will have the power to detect population trends, provide information on population demographics, and assess geographic differences within PWS. This project is allied with harlequin duck studies being conducted as part of the continuation of the Recovery of Nearshore Vertebrate Predators (project /025). It is essentially a continuation of Project /027 Harlequin Duck Recovery Monitoring with an added component for identifying breeding areas. No work was conducted on project /027 in FY99. This project will continue to monitor harlequin duck populations in oiled and unoiled areas of PWS. However, we will now conduct surveys, one per year, during March. Throughout much of the year, harlequin duck populations are in a state of flux as birds move to and from breeding areas. Subadults may also be quite mobile in a quest to find mates. March is a period when pair bonds are well formed, and there is relative stability in both numbers and movements of harlequin ducks.

NEED FOR THE PROJECT

A. Statement of Problem

Harlequin ducks have not recovered from the effects of the *Exxon Valdez* oil spill. Populations in oiled areas are continuing to decline (Rosenberg and Petrula 1999). Declining molting populations, coupled with low female survival, and exposure to hydrocarbons in oiled areas are all indicative of a lack of recovery and continued oil spill effects. Residual oil in the nearshore environment has the potential to interfere with physiological processes. Two main hypotheses have been presented to explain population declines: (1) ingested oil is continuing to cause either mortality and/or sublethal impairment of reproduction; and/or (2) initial mortality caused significant losses to the western PWS population which may result in a protracted recovery period.

However, questions still remain as to the cause of this decline, and whether survey results primarily reflect lingering effects of the oil spill or extrinsic factors such as local ecology and climate at the breeding, molting, or wintering areas. Long-term monitoring, to assess population fluctuation within PWS and population trends between oiled and unoiled areas has not been conducted.

B. Rationale/Link to Restoration

This proposed work represents a relatively simple, workable approach to the long-term monitoring of harlequin duck populations that will allow us to assess recovery from the spill. We propose a survey that will have the power to detect trends in oiled populations, give us valuable information on population demographics, and provide insight into geographic differences within PWS. This study is directly linked to the recovery objectives for harlequin ducks in the EVOS Restoration Plan (Exxon Valdez Oil Spill Trustee Council 1999). This project will provide winter population trends; compare population structure, and provide an index of recruitment between oiled and unoiled areas.

Information from this project will aid in the development of a population model. A population model is central to monitoring harlequin duck recovery. The model must include demographic parameters and identification of critical periods of the annual cycle that may limit recovery from the *Exxon Valdez* oil spill. This will allow researchers to predict population trends and rate of recovery. While some of this information has been collected for PWS populations (Holland-Bartels in prep.; Rosenberg and Petrula 1999) and harlequin ducks in North America (Goudie et al. 1994; Robertson 1997), many specifics are still lacking, including data on productivity, recruitment, dispersal, and subadult survival. Population monitoring will test the demographics predicted by the model.

Harlequin ducks are highly philopatric to breeding, molting, and wintering sites. This is an adaptive strategy in natural situations and predictable environments. It is not favorable in the face of dramatic environmental perturbations or rapidly changing land-use practices. It does not favor rapid recovery and colonization of new undisturbed sites. This strong philopatry may result in continued exposure to residual oil or delays in pioneering new nest sites once populations stabilize. Monitoring provides a direct approach to assess recovery.

It takes a minimum of three years before population trends can be determined. Therefore, monitoring should begin as soon as possible. Annual monitoring is proposed. Populations may vary considerably from year to year. Detecting upward or downward trends in abundance and productivity from year to year variations will be met sooner with increased sampling. Results of this work will have a direct bearing on assessing the status and outlook for this resource and help guide agency programs and policies related to public uses, especially subsistence and recreational hunting, land-use practices, and wildlife viewing.

C. Location

The proposed project will be conducted in the oil spill area of western Prince William Sound and unoiled eastern PWS between Valdez and Cordova and northern Montague Island. ~~Late summer survey will repeat transects surveyed in /427 Harlequin Duck Recovery Monitoring (Rosenberg and Petrula 1999~~). March survey sites in PWS will be located in the same areas of Montague Island used by the harlequin duck component of project \025 Nearshore Vertebrate Predator Project and sites surveyed by project \427 Harlequin Duck Recovery Monitoring (Rosenberg and Petrula 1999.). Additional transects will be located in southwestern PWS following reconnaissance in the summer of 1999. Surveys in the spill area will focus on Knight Island, Applegate Island, Foul Bay, Main Bay, Eshamy Bay, Crafton Island, Chenega Island, Green Island, Naked Island, and Bainbridge, Evans, and LaTouche islands in southwestern PWS. Surveys in non-oiled areas will include portions of Hinchinbrook Island, Simpson Bay, Sheep Bay, Port Gravina, Landlocked Bay, Bligh and Busby islands, Galena Bay and Valdez Arm, and Montague Island. Communities affected by the project include Chenega, Tatitlek, Whittier, Valdez, and Cordova.

oversight — should have been deleted. SS

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The project will continue to inform and coordinate our community involvement activities. This effort began with project /427 (Harlequin duck recovery monitoring) and a TEK report is included in Rosenberg and Petrula (1999). This effort was continued with project /273 (Scoter life history and ecology: linking satellite telemetry with traditional ecological knowledge). The collection of indigenous knowledge has been coordinated with Dr. Henry Huntington, TEK specialist Chugach Regional Resources Commission and Hugh Short, Community Coordinator, EVOS Restoration Office. We will continue to solicit advice from the above parties and gather information on TEK through synthesis workshops, local community facilitators, and residents as part of project /273.

Efforts have and will continue to be made throughout the restoration process to participate in and provide public involvement in the design and implementation of this project. In concert with project /273 information gathered from this project will be shared with local communities. Study plans and results of project /427 and project /273 have been presented in the oil spill communities of Tatitlek, Chenega Bay, Cordova, Port Graham, Nanwalek, and Seldovia and at meetings of community facilitators. We will continue with this effort. Project staff has and will continue to present information to local communities or prepare articles or photographs for Trustee Council publications. Boat and air charter contracts, and other services will be contracted from local sources when possible.

PROJECT DESIGN

1. Surveys

A. Objectives

1. Compare population structure (number of breeding pairs, subadult males, adult males, and females) between oiled and unoiled areas during March.

2. Estimate density for oiled and unoiled survey sites in March.

3. Compare annual changes in density and population structure for oiled and unoiled survey sites.

4. Compare annual changes in density and population structure *within* oiled and unoiled survey sites during March.

5. Compare results with EVOS project /427 Harlequin Duck Recovery Monitoring.

B. Methods

This study will test the following hypotheses:

1. Objective 1.
   H_o: The ratio of males to females; total ducks to subadult males; and breeding pairs to total ducks is the same for oiled and unoiled populations during March.

   H_1: The ratio of males to females; total ducks to subadult males; and breeding pairs to total ducks is different for oiled and unoiled populations during March.

A generalized logit model (Agresti, 1990) will be used to test differences in population structure for oiled versus unoiled survey sites for winter and late-summer for objectives 1 and 2. Male:female ratios for individual survey periods will be compared by estimating proportions using cluster sampling (flocks) (Cochran, 1977).

2. Objective 2. No hypothesis is being tested.

3. Objective 3.
   Ho: The rate and direction of population change between years is the same for oiled and unoiled survey sites.

   H_1: The rate and direction of population change between years is different for oiled and unoiled survey sites.

Density changes will be tested by regression and population structure will be tested with logistic regression (Agresti, 1990).

4. Objective 4.
H_0: The rate and direction of population change between years is the same within oiled and unoiled survey sites.

H_1: The rate and direction of population change between years is different within oiled and unoiled survey sites.

Density changes will be tested by regression and population structure will be tested with logistic regression (Agresti, 1990).

5. Objective 5. No hypothesis is being tested.

March surveys. Surveys will be conducted in representative portions of oiled areas in western PWS and unoiled areas in eastern PWS. FY 95-97 survey routes will be repeated (Rosenberg and Petrula 1997). Surveys will be conducted from approximately March 8 through 20. Repeat surveys will not be conducted and surveys in oiled and unoiled areas will not be conducted simultaneously because population flux is expected to be minimal at this time of year. New surveys will be established in areas of northern Montague Island and southwestern PWS with known concentrations of birds. All harlequin ducks will be recorded along each survey route. Observations will be recorded as pairs or by sex, and males will be divided into two age groups using predetermined criteria (Rosenberg and Petrula 1999.). Surveys will be conducted from open skiffs up to 20 feet long. Each skiff will have two observers. Surveys will be conducted from within 30 meters of shore along predetermined routes. A pace and course will be chosen that will assure complete coverage of the survey area and maximize the opportunity to see ducks. All transects will be mapped and all observations will be recorded by date and location and mapped by flock. Exxon Valdez oil spill beach segment modifiers (oiled areas), habitat associations, time, and weather will be noted.

Population composition and annual changes in density will be compared to test whether harlequin duck populations are exhibiting similar growth trends or the oiled (injured) population is exhibiting a different direction or rate of change. We will continue to test whether low reproductive success in oiled areas has resulted in changes in population age and sex structure. The proportion of first-year males to total males will be used as a measure of past reproductive success. Proportions of paired birds and male:female ratios will be compared for oiled and unoiled sites to indicate breeding propensity. Surveys will be used to detect changes in abundance and compare the direction and rate of change between years for the two survey areas. Surveys within oiled and unoiled areas will be compared to determine if geographic differences are detectable. Data from FY95-FY97 surveys will be incorporated into the analysis when applicable.

Sufficient power to test the hypotheses presented above (detecting a significant difference in slopes) is expected for this project based on the power generated from project \427, Harlequin Duck Recovery Monitoring (Rosenberg and Petrula 1999). Using similar survey techniques and time frames that project was able to reject the null hypothesis (no difference in rate of population change between oiled and unoiled areas) with the following power:

Power at alpha = .05	**.80**
Power at alpha = .10	**.88**

C. Cooperating Agencies, Contracts, and Other Agency Assistance

ADF&G personnel will conduct all data collection and analysis. Winter surveys, and contracts for vessel support for winter surveys, will be coordinated with related USGS-BRD sea duck projects and ADF&G project /273 (Scoter life history and ecology:linking satellite telemetry with traditional ecological knowledge). Private sector contracts for winter vessel support will be solicited.

SCHEDULE

A. Measurable Project Tasks for FY 00

October 1999	Project start-up. Interagency coordination. Plan logistics and personnel for winter surveys. Contract for vessel support.
Jan. –Feb. 2000	Hire seasonal technicians for March survey. Prepare field equipment. Finalize field logistics.
March 2000	Conduct winter surveys in PWS.
April – May 2000	Create databases, GIS. Analyze field data and begin report preparation. Maintain equipment.
June - July 2000	Analyze data
July-Aug-Sept 2000	Analyze data and begin report preparation
April 2001	Annual Report submitted

B. Project Milestones and Endpoints

FY00

October-February: Coordinate and plan surveys, prepare equipment, contract for vessel support, hire personnel.
March: Conduct population surveys.
April-September: Data analysis and report preparation, maintain equipment.
April 15: Submit annual report.

FY01

October-February:	Coordinate and plan surveys, prepare equipment, contract for vessel support, hire personnel.
March:	Conduct population surveys.
April-September:	Data analysis and report preparation, maintain equipment.
April 15:	Submit annual report.

FY02

October-February:	Coordinate and plan surveys, order transmitters, prepare equipment, contract for vessel support, hire personnel.
March:	Conduct population surveys.
April-September:	Data analysis and report preparation, maintain equipment.
April 15:	Submit annual report.

This is a projected three-year monitoring program designed to assess the recovery of an injured species. Each project objective will be assessed annually for oiled and unoiled areas then compared with each other and with data collected in subsequent years. Year to year trends will first be compared in 2000 and then each year after. At the end of each year results will be compared with the restoration goals to assess whether recovery has occurred.

C. Completion Date

Under present guidelines, Harlequin ducks will have recovered when breeding- and nonbreeding-season densities return to prespill levels. An increasing population and decreasing exposure to hydrocarbons in oiled parts of PWS will indicate that recovery is underway (Exxon Valdez Oil Spill Trustee Council, 1999). This project will compare harlequin duck population structure and abundance between oiled and unoiled areas and within geographic areas. This study will be completed when oiled and unoiled populations exhibit similar structure and population trends (accounting for geographic differences) and the oiled population is no longer declining. Until further information is gathered it will not be possible to predict when densities will return to prespill and populations will exhibit a positive trend. This project may also discover new information that will suggest changes to the Recovery Objectives.

PUBLICATIONS AND REPORTS

Annual reports will be presented to the Chief Scientist by April 15. Reports will include survey areas, population structure and abundance and movements and timing of marked birds. A final report will be prepared at the end of the proposed monitoring schedule unless continued monitoring is warranted or when recovery objectives are met. Special reports (publications) will be prepared during the course of the monitoring effort if warranted. Publications will be prepared for peer-review journals when sufficient data has been collected to warrant manuscript preparation.

PROFESSIONAL CONFERENCES

Harlequin duck Working Group. Time and date to be determined.

NORMAL AGENCY MANAGEMENT

There are no other agency or non-agency contributions to this project. ADF&G is not required to conduct these surveys by statute or regulation. Limited staffing and funding precludes ADF&G from undertaking these surveys as part of normal operations and in the past ADF&G has not conducted marine bird surveys in PWS as part of its normal waterfowl management functions.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This research relies on incorporation of methods and information from other EVOS Trustee sponsored research, including projects /427, and /025. Equipment purchased by /427 will be used to conduct this research. Location of research sites, and data collection and analysis will follow previously established protocols. Equipment and logistics will be shared with project \273 Surf Scoter Life History and Ecology: Linking Satellite Telemetry with TEK to Conserve the Resource. All efforts will be made to coordinate surveys and share vessel support and equipment with USGS-BRD projects and project /273. Personnel with ADF&G and USGS-BRD will assist each other when possible.

This project will be integrated with ongoing studies or findings of past studies including project \273 Surf Scoter Life History and Ecology: Linking Satellite Telemetry with TEK to Conserve the Resource, \052B Traditional Ecological Knowledge; project \025 Nearshore Vertebrate Predator Project; project \427 Harlequin Duck Recovery Monitoring; and project \159 Prince William Sound Marine Bird and Mammal Surveys.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

This is a new project.

PROPOSED PRINCIPAL INVESTIGATORS

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Revision 7 1-99
approved TC 8-9-99

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

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$34.8						
Travel		$2.8						
Contractual		$18.1						
Commodities		$1.6						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$57.3			Estimated FY 2001	Estimated FY 2002		
General Administration		$6.5						
Project Total	$0.0	$63.8			$71.0	$71.0		
Full-time Equivalents (FTE)		0.6						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Project Number: 00407
Project Title: Harlequin Duck Population Dynamics
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Prepared:4/4/99,Rev7/7,7/22,7/2

2000 EXXON VALDEZ TRUSTEE 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
D. Rosenberg	WBIII, Principal Investigator	18J	2.2	6.5		14.3
Mike Petrula	WBII, survey and data analysis	16B	2.5	4.5		11.3
C. Barnhill	Cartographer II	16L	0.5	5.2		2.6
2 F&G Tech.	F&G Tech. III, Field Technician	11F	1.5	3.7	1.0	6.6
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		6.7	19.9	1.0	
					Personnel Total	$34.8

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
Portage-Whittier Alaska Railroad vehicle,boat, and 1 psng.	0.4	2			0.8
Portage-Whittier Alaska Railroad vehicle and psng.	0.1	2			0.2
Portage-Whittier Alaska Railroad Psg. fare	0.1	1			0.1
Per diem Whittier			4	0.1	0.4
Travel to Harlequin duck working group symposium	0.8	1	5	0.1	1.3
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$2.8

FY00

Project Number: 00407
Project Title: Harlequin Duck Population Dynamics
Agency: ADFG

FORM 3B
Personnel
& Travel
DETAIL

Prepared:4/4/99,Rev7/7,7/22,7/2

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

Contractual Costs:	Proposed
Description	FY 2000
Boat and outboard motor repair and maintenance	1.0
Photo processing, presentation productions	0.4
Air charter for field support 4 hrs @ $270/hr	1.0
Trailer and boat moorage Whittier	0.1
Vessel support for March surveys 12 days @1300/day	15.6
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$18.1

Commodities Costs:	Proposed
Description	FY 2000
Boat fuel 300 gallons @ $1.50/gal	0.5
Boat supplies- replacement parts, props, fuel lines, fuel filters, water filters, battery, absorbent rags, oil, emergency provisions	0.8
Field survey supplies- rite-in-rain notebooks/paper, nautical charts, batteries,	0.3
Computer software for analysis, graphing, mapping, SAS licensing	0.0
Commodities Total	$1.6

FY00

Project Number: 00407
Project Title: Harlequin Duck Population Dynamics
Agency: ADFG

FORM 3B
Contractual &
Commodities
DETAIL

Prepared:4/4/99,Rev7/7,7/22,7/2

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
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
			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
20 ft. Caribe rigid hull inflatable	1	ADFG
17 ft. Boston Whaler	1	ADFG
10x40 binoculars	4	ADFG
Spotting Scopes	2	ADFG
Achilles 8 ft inflatable dinghy	2	ADFG
Remington Shotguns	2	ADFG
Survival Suits	2	ADFG
Outboard Motors/various hp	6	ADFG
Magellan GPS	3	ADFG
Marine VHF radios	4	ADFG

FY00

Project Number: 00407
Project Title: Harlequin Duck Population Dynamics
Agency: ADFG

FORM 3B
Equipment
DETAIL

Prepared:4/4/99,Rev7/7,7/22,7/27

Revision 7-30-99
approved TC 8-9-99

Development of a Web-Based System for Communicating Ecosystem Research Results to the Public

Project Number:	00414-BAA
Restoration Category:	Research
Proposer:	J. Allen/AK Digital Graphics
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	New
Duration:	1st yr. 1 yr. project
Cost FY 00:	$26.8
Cost FY 01:	$0.0
Cost FY 02:	$0.0
Geographic Area:	All
Injured Resource/Service:	All

ABSTRACT

Ten years after the oil spill there exists a compelling need for translation and communication of scientific results to stakeholders. Interactive web communications offer a powerful tool for information transfer. This project will develop an architecture and content for interactive, web-based, multimedia delivery of ecosystem research results to the public. The web display will present highlights from the restoration research projects with emphasis on ecosystem synthesis, using a format that is appealing, informative, and understandable. This work will be conducted in close consultation with Trustee Council staff. Products will reside as a linked modular unit on the Trustee Council's web site.

CONTENTS

INTRODUCTION

Background

The *Exxon Valdez* oil spill (EVOS) was a tragedy of indescribable proportions whose impacts on the environment, wildlife and people of the region are still evident. There remains great public demand for access to understanding of the consequences.

One, perhaps the only, positive aspect to the disaster is the unprecedented scientific knowledge that has been gained. The spill-affected area has become one of the most thoroughly studied ecosystems in the world. Over $108 million has been invested to date in research and monitoring projects in a wide-ranging and comprehensive scientific program. Scores of individual projects have helped define the status of injured resources, understand mechanisms of injury, and track recovery. Three large scale, multidisciplinary, ecosystem-level investigations have dramatically increased our understanding of how the ecosystem works and what factors may be constraining recovery.

For practical purposes, however, the new knowledge is useful only if it can be accessed and understood. An immediate barrier arises from the fact that scientific products are delivered in a way that impedes intelligibility to non-scientists, a fact that can incite frustration among the public and resource managers. As the restoration research programs draw to a close there exists a compelling need for translation and communication of accumulated scientific results to stakeholders. It is important to establish channels of communication by which technical research results can be transferred with meaning and context, and via which results and data can continue to be accessed into the future.

Existing Work

The EVOS Trustee Council (EVOSTC) has made information delivery a priority. In addition to its annual public workshop, printed quarterly updates, annual status reports, and library of project final reports in hard copy, the EVOSTC office offers a bibliography of peer reviewed publications, a basic information database on funded projects on CD-ROM in FileMaker Pro, and a GIS database on CD-ROM in ArcView, and a set of written narratives organized by species (the *Restoration Notebook* series). The existing EVOSTC web site provides entry to either access or locate all of these information products.

The EVOSTC has also supported this investigator in production of graphical presentations related to the SEA program (project 99361). This work makes use of advanced visual communications techniques with results that have been well received by wide audiences. A related videotape on the SEA program is currently in development, also funded under project 99361. This production has much reduced technical emphasis and will serve a lay audience via VHS video and possibly television.

In the first group of projects listed above, the emphasis is on (1) describing damage and recovery status by species and (2) cataloging the funded projects and their objectives. There is an emphasis on textual material and so far little presentation of translated research results. The work of project 99361 has added another complementary facet: use of dynamic visualization and presentation techniques to communicate complex concepts in an understandable way, focusing thus far on complex results from the SEA program.

The new project proposed here will build on the achievements of project 99361 by extending its techniques beyond SEA to wider syntheses of EVOSTC research findings, and presenting the results in a dynamic, interactive web-based format incorporated into the EVOSTC web site.

Advantages of Interactive, Web-based Multimedia for Information Transfer

One of the biggest challenges in translating science for general audiences is to simplify enough that the material is easily understandable, but not so much that inaccurate perceptions are created. Using traditional techniques alone it is quite difficult to bridge the gap between a superficial, newspaper-level representation of the results on the one hand and the scientist's own delivery of the results, with all the caveats, qualifiers and context entailed, on the other. For the most part, this intermediate area remains unserved, yet is the level increasingly requested by the public. The positive public response to pilot efforts within the SEA program has raised our awareness to the extent of this need and has provided evidence for the value of multimedia approaches.

Multimedia is the combination of varied elements, including text, sound, graphics, images, animation and motion video, into a cohesive communications vehicle. Picture-oriented display techniques provide a powerful communication tool because they take advantage of the highly developed information processing/comprehension abilities of the human visual system (Gershon, 1994). Graphical displays enables "high bandwidth" information transfer and can enhance comprehension through intuitive illustration of concepts and complex relationships. Addition of time-based media (motion and sound) opens up further possibilities. Especially useful to us are the capabilities for progressive visual unfolding of information, animation of changes over time, and augmentation of visual imagery by narrative, music and sounds. Further, multimedia yields measurable benefit through its ability to gain and hold attention and interest. Presentation of information via multiple modalities including visuals, sound, and motion, has been shown to improve retention rates, learning speed, attention levels, credibility and overall impact of presentations (Lindstrom, 1994; Vaughan, 1998).

Interactive multimedia is distinguished by non-linear organization of content and active control by the user over what is seen, in contrast to the linear organization and passive viewing associated with live presentations and movies. A considerable body of education and psychology theory exists to support the belief that interactivity enhances information transfer (reviewed by Wilson, 1993). Interactive multimedia is seen as "allowing users to follow their own associationist paths, to experiment and build their own cognitive structures, and to link their actions with internal...needs" (Wilson, 1993). From a practical standpoint, many of the benefits of interactivity are related to improved retention, relevance, access and motivation. Instruction delivered by interactive multimedia can increase retention rate up to 3-fold over use of audio stimulation alone, and it doubles retention above that achieved with audiovisual stimulation but no interactivity (summarized by Lindstrom, 1994). Interactivity also increases the chance that information received will be relevant to a user's interest, not only because the user chooses the topics displayed, but also because the interactive structure allows hierarchical delivery of information. Levels of complexity can be accessed on command, according to the user's interest, but all details need not be shown to every user. This helps shield the user from information overload, as might occur in a printed publication at similar depth, but yet makes in-depth, context-sensitive details available as needed. User satisfaction is influenced both by the perceived pertinence of the information and the perceived sense of boundlessness of information available for the asking. Motivation of users to engage in the knowledge transfer process follows from the fun and entertainment value of the experience as well as the quality of the information received and the freedom to form knowledge linkages that address immediate needs of the individual.

The above concepts of electronic "information on demand" are currently fueling the web-based information revolution. The web itself is a specialized example of interactive multimedia, and affords the added advantage of immediate, virtually universal access with a single maintenance site. Increasingly efficient technology for file compression and streaming video delivery, such as Shockwave™ video formats, offer expanding possibilities for web delivery of multimedia-rich applications. Together with scrupulous attention to file size and program organization, this can enable delivery of an enhanced graphic experience via the web even within existing bandwidth limitations. As an added benefit, such applications created for the can also be suitable for transfer to CD-ROM or for use as standalone live presentation segments.

Role of This Project

This project will develop programming architecture and content for interactive, web-based multimedia delivery of ecosystem research results to the public. The product will reside as a linked modular unit on the EVOSTC web site. The content will feature highlights from EVOSTC restoration research projects, with emphasis on ecosystem processes and cross-project synthesis. This interconnected, searchable science area will be designed to serve the general public and will present information in a format that is appealing, informative and understandable. Content will be developed in consultation with participating EVOSTC investigators. Decisions regarding overall design and artistic attributes will be made in collaboration with EVOSTC staff, with scientific components subject to review by the EVOSTC Chief Scientist or Science Advisor.

NEED FOR THE PROJECT

A. Statement of the Problem

What is the problem to be addressed? Which injured resource or service is it designed restore?

In order for the goals and value of EVOSTC-funded restoration research to be fully realized, it is important that new knowledge be disseminated to stakeholders and decision makers. Knowledge transfer is an important step in ensuring a more informed basis for restoration activities, resource management and design of future long-term monitoring plans. The task of communicating complex scientific results to a non-specialist audience, however, is challenging.

B. Rationale/Link to Restoration

Why should the work be done? Discuss how the project will address the problem.

The work proposed here will assist in communicating to the general public the new understanding that has resulted from EVOSTC research programs. Web-based interactive multimedia will provide an effective vehicle for wider knowledge transfer by illuminating difficult concepts and delivering needed information in an accessible, engaging, useful and entertaining manner. Successful completion of this work will assist the Trustee Council and the public "to view the effects of the oil spill and the long-term restoration management of injured resources and services from broad, multi-project and ecosystem-level perspectives. Having the benefit of these perspectives will not only aid interpretation of past results in regard to injury and recovery, but will also provide an improved framework for development of long-term restoration, research, monitoring and management plans."
(EVOSTC, 1999b).

C. Location

Where will the work be done? Where will its benefits be realized?

The bulk of the work will be performed at the offices of the EVOSTC and of Alaska Digital Graphics in Anchorage, with additional time at the Prince William Sound Science Center in Cordova.. Benefits will be realized throughout the spill-affected area.

COMMUNITY INVOLVEMENT

How will affected communities be informed of the project and provide their input?

Affected communities will be informed of the existence and progress of the project via links on the existing EVOSTC web site, SEA web site, and (by request to) other related web sites; as well as by announcement in the EVOSTC newsletter. Upon completion the new web modules will be announced to the major search engines and web address listing services. Users of the site will be encouraged to give feedback and suggestions via simple online comment forms.

PROJECT DESIGN

A. Objectives

The objectives of this project for FY00 are:

1. To develop and program an architecture for a dynamic, interactive, web-based display of ecosystem research results, organized as a searchable, interconnected, cross referenced set of hierarchical modules which are to be linked to the EVOSTC web site and delivered to the internet via the EVOSTC web server.

2. To create prototype software content for these science modules featuring selected highlights of EVOSTC funded research, with emphasis on cross-project synthesis and ecosystem-level conclusions, at a level suitable for the general public, in a format which is both appealing and informative.

3. To formulate a plan for further content development and longer term maintenance to ensure continued utility of the site.

B. Methods

I. General Considerations

1. Liaison with EVOSTC Office.

The proposed ecosystem science modules will reside as a unit on the existing EVOSTC web server. The main access will be from the top level of the EVOSTC web site, with other entry points provided throughout the existing site as desired. The 'look and feel' of the proposed science unit is subject to approval by the EVOSTC Director or designee.

The EVOSTC office has an expertly staffed communications office which has been responsible for a number of outstanding audio-visual and print productions as well as the existing web site. It is not the intent of this project to duplicate existing functions; rather it is hoped that this project will augment existing efforts by offering some additional expertise in the specialties of web-based programming and scientific content. The proposed work will coordinate closely with the communications office, including free sharing of media and concepts. A major goal will be to avoid any duplicative effort, maximize use of existing resources, and obtain a synergistic shared result.

2. Liaison with EVOSTC Researchers

This investigator is mindful of the responsibility involved in presenting to the public the research results of other scientists and is committed to working closely with participating EVOSTC investigators. Segments will not be considered complete until the originator of the research is satisfied with the representation. The EVOSTC Science Advisor, and/or Chief Scientist, or designee, will have opportunities for review of scientific content.

II. Hardware

- All work will be conducted in an IBM-compatible PC environment in order to be fully compatible with the Micron/P2 Windows NT 4.0 platform in use by the EVOSTC office.
- Advanced video and graphic creation tasks will be performed on a high end portable graphics station (IBM ThinkPad 770-Z) to be purchased separately by Alaska Digital Graphics.
- Web coding and CGI programming will be performed *in situ* on the EVOSTC server.

III. Software*

- Visual Basic will be used for CGI programming in order to conform with the EVOSTC platform; this replaces the PERL language customarily used on Unix systems.
- Java, Javascript, Macromedia Director with Shockwave, and GIF animations will be used for dynamic interactive content and/or animated demonstrations.
- The concept-based Excite search engine will be used for search functionality.
- Most HTML coding will be specialized and performed by hand in a plain text editor on the server, without a commercial environment. Some coding will utilize Macromedia suite tools including Fireworks, Dreamweaver and Backstage.
- The utility Debabelizer will be used to optimize color palettes and thus minimize image size; this is necessary to optimize module performance at web-limited bandwidths.
- In addition the investigator has experience with the following core software which will be used in development of multimedia elements:
    - Adobe PhotoShop 5.02 - image creation and manipulation
    - Adobe Premiere 5.1 - professional-level digital video editing
    - Adobe AfterEffects 3.1 - professional-level special effects
    - Macromedia Director 7.0 - multimedia authoring system
    - Macromedia Shockwave - streaming video creation
    - Sound Forge - digital audio editing
    - Bryce 3D - 3 dimensional landscape creation
    - Micrografx Simply3D and Flowcharter - 3D object and charting utilities
    - Corel Graphics Suite 8 - used for CorelDraw - vector based graphics.

** With the exception of Visual Basic and Debabelizer, all of the above software is currently in use by the PI and available to the proposed project at no new cost.*

- The completed web unit will be delivered to the internet via the existing EVOSTC server, which is the Netscape Enterprise Suite server, V 2.0.

IV. Design Criteria

The objective for this web project is to produce at minimum a third generation website as defined by Siegel (1997), added to which will be enhancements for interactivity (Szeto et al, 1997), plus specialized custom-programmed segments for selected demonstrations.

Following is a list of design guidelines to be used:

1. *Overall*
   - Design for the needs of the user.
   - Maintain consistency and simplicity.
   - Place premium importance on an excellent navigation system due to the large volume of information to be explored.
   - Emphasize interactivity. Incorporate the foundations for interactivity at the top level of design. Ensure that interactivity rules can be internalized easily by users for intuitive control over the experience as they progress deeper into the site.
   - Emphasize use of graphics, animated demonstrations and other multimedia elements to ensure a rich experience and improve information transfer.
   - Take care with high quality 'packaging' to enhance esthetic appeal, especially on first arrival at the opening page.

2. *Interface*
   - Aim for smooth fit of form and function in an interface which looks good and gives accurate representation of the underlying behavior layer.
   - Maintain strict consistency in navigation elements. Keep top level (internode) elements present on all pages. Sublevel (intranode) menus and palettes depend on context but are always kept at the same location on the page with the same look-and-feel.
   - Incorporate judiciously such techniques as text and image rollovers, dynamic expanding menus, detailed cross-referencing, searchability, and forms-based CGI programming for customized returned information.
   - Use clickable maps where appropriate to organize information.
   - Use audio cues as well as visual where appropriate.

3. *Speed*
   - Plan for physical bandwidth limitations at the typical connection speed of users (28.8K).
   - Use optimized color palettes and image compression to reduce image size.
   - Use graphic interlacing, sequential loading, and intelligent selection of place holders to engage the user's attention while large items are transferred..
   - Take full advantage of new video streaming technology using Shockwave™ to deliver animations, demonstrations and audio/video segments.

4. *Measures of success*
   - Web site traffic: track and analyze user visits by date, domain of origin, web sections visited, order of progression through site (general), and duration of stay (general).
   - Email responses: solicit feedback on site, provide users with easy tools for submitting comments.

V. Layout/Structure

The envisioned plan is for a nodal structure model at the top level and hierarchical organization below. The opening page gives a clear indication of content of each section. A linear entry "tunnel" provides a clear message about the experience ahead and sets the tone for the site. A linear exit segment offers opportunities for feedback. Any individual page is always only one click away from the top page and from the search engines. Links consistently present provide access to a location-sensitive menu of pages about related issues; as well as to topic-related video clips, HTML segments, other web sites, and other reference sources.

An outline of one possible architecture model is shown below (Figure 1).

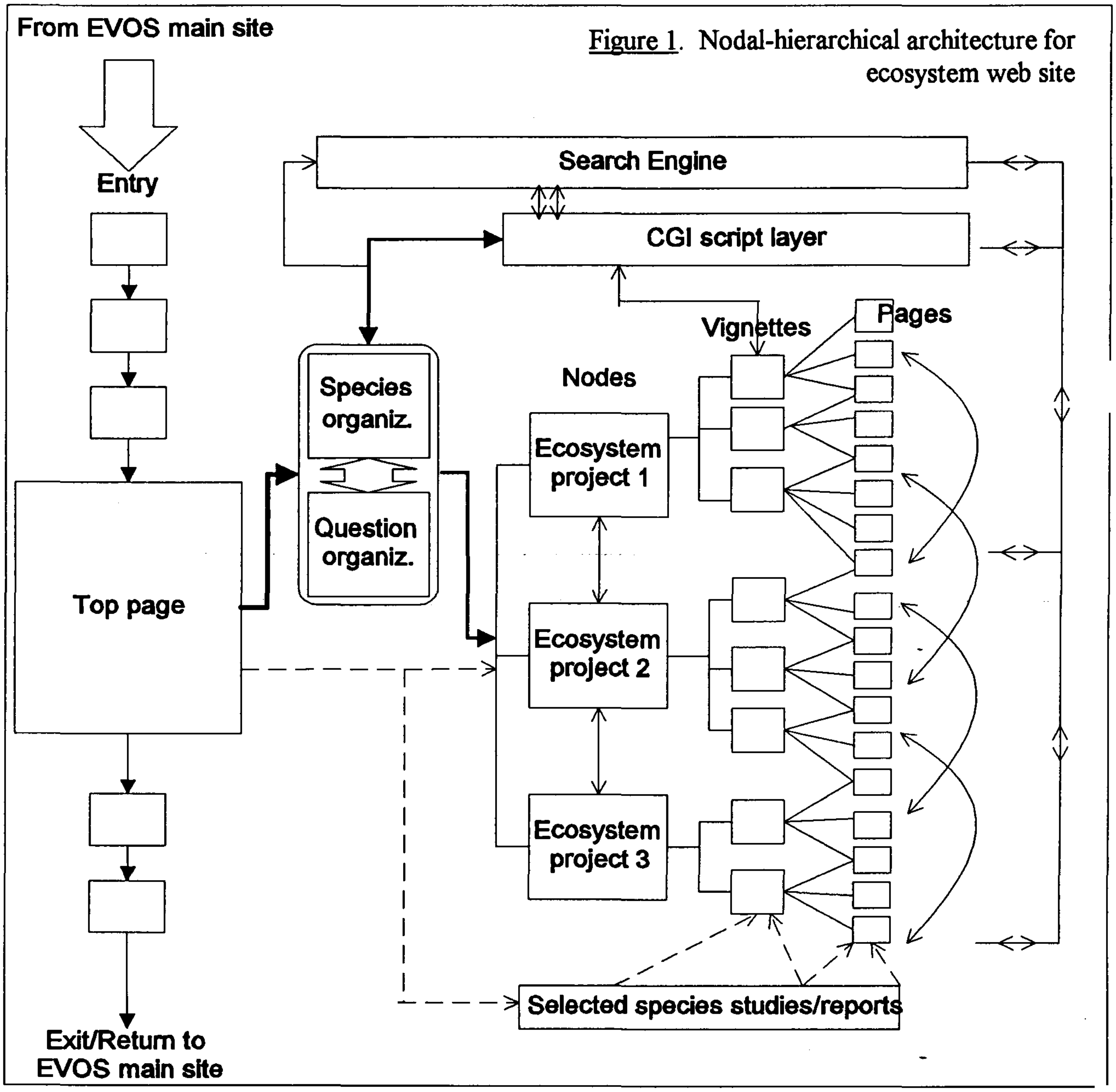

Figure 1. Nodal-hierarchical architecture for ecosystem web site

VI. Content

1. Science Content

The proposed science unit will focus initially on synthesized results from the three ecosystem projects:

- Alaska Predator Ecosystem Experiment (APEX), Lead Scientist: David Duffy, Key Question: Are forage fish distributions limiting recovery of seabirds from the spill?
- Nearshore Vertebrate Predator program (NVP), Lead Scientist: Leslie Holland-Bartels, Key question: What is limiting recovery of sea otters, river otters, harlequin ducks, and pigeon guillemots: is it food or is it oil exposure?
- Sound Ecosystem Assessment (SEA), Lead Scientist: Ted Cooney, Key question: What ecosystem factors constrain production of young pink salmon and herring?

Emphasis will be placed on conveying big picture results and on forging connections between the findings of the three ecosystem programs where possible. Annual and final reports from these programs will be used as the primary information source. Additionally, synthesis manuscripts currently in preparation by these groups will provide valuable material about SEA, NVP (if available) and APEX (when completed). Translation and abstraction of core findings will rely heavily on assistance to be sought from the Lead Scientists and principal investigators.

In addition, selected, key, single-species studies which bear on the above ecosystem questions, or whose objectives the ecosystem projects have assisted, will be referenced and incorporated in the site to the degree that time permits. Candidates for inclusion will be selected in consultation with EVOSTC staff. Those not able to be included because of time constraints will be incorporated into the plan for future site development.

2. Multimedia Content

This work will leverage previously generated multimedia segments created by this investigator for the SEA program. In interests of cost effectiveness and time saving, new creative work will focus on original interpretive animations and demonstrations, while supporting elements such as photos and video segments will as far as possible be drawn from EVOSTC archives.

3. A Note on Time Constraints for Content Generation

The time allocated for the principal investigator in this proposal has been reduced to less than three months from the originally requested six. Although less time will be needed for hardware issues (with web delivery instead of kiosks), there is still a shortfall in content development time. It is felt that the goals of the project can still be met, however, through the adjustments noted above, namely:

- Prioritization of topics to the ecosystem projects, with other areas incorporated as outlines and in a plan for future development;
- More reliance on existing multimedia segments and less on new creations;
- More dependence on access to supporting material (photos, video) from EVOSTC archives.

SCHEDULE

A. Measurable Project Tasks for FY 00

Measurable project tasks for FY00 include

- Content selection*
- Draft of content narrative and sketch of components*
- Review and approval by Lead Scientists
- Programming of interactive elements*
- HTML coding and media incorporation in modules*
- Site activation by sequential addition of modules to web server
- Analysis of user feedback and access statistics.

** in consultation with EVOSTC staff*

B. Project Milestones and Endpoints

MILESTONE / DELIVERABLE **(assuming funding commences October 1)**	**DATE**
Draft narrative and sketches available.	December 31, 1999
Three core modules deployed; additional modules under construction; access tracking ongoing	September 30, 2000
Final report (including access statistics, feedback results, and straw plan for future development) delivered.	April 15, 2001

C. Completion Date

The anticipated completion date is September 30, 2001 (for core web components) and April 15, 2001 (for analysis of access statistics and user feedback).

Revision - 30-99
Approved TC 8-9-99

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$25.0						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$25.0		Estimated FY 2001	Estimated FY 2002			
General Administration		$1.8						
Project Total	$0.0	$26.8		$0.0	$0.0			
Full-time Equivalents (FTE)		0.2						
	Dollar amounts are shown in thousands of dollars.							
Other Resources		$7.0						

Comments:

IBM Thinkpad 770-Z and accessories to be purchased separately by Alaska Digital Graphics ($7.0K)

FY 00

Prepared: 07/30/99

Project Number: 00414
Project Title: Web-based Communications Development
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$17.6						
Travel		$0.8						
Contractual		$1.3						
Commodities		$1.1						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$20.8		Estimated FY 2001	Estimated FY 2002			
Indirect		$4.2						
Project Total	$0.0	$25.0		$0.0	$0.0			
Full-time Equivalents (FTE)		0.23						
	Dollar amounts are shown in thousands of dollars.							
Other Resources		$7.0						

Comments:

IBM Thinkpad 770-Z and accessories to be purchased separately by Alaska Digital Graphics ($7.0K)

FY 00

Prepared: 07/30/99

Project Number: 00414
Project Title: Web-based Communications Development
Name: Jennifer R. Allen
Agency: NOAA

FORM 4A
Non-Trustee
SUMMARY

FY 99 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
Jennifer R. Allen	Info Systems / Communications Specialis		2.7	6.5		17.6
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		2.7	6.5	0.0	
					Personnel Total	$17.6

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
					0.0
Anchorage-Cordova	0.20	1	10	0.00	0.2
Anchorage-Fairbanks	0.20	1	4	0.10	0.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$0.8

FY 99

Prepared: 07/30/99

Project Number: 00414
Project Title: Web-based Communications Development
Name: Jennifer R. Allen
Agency: NOAA

FORM 4B
Personnel
& Travel
DETAIL

FY 99 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Contractual Costs:	Proposed
Description	FY 2000
telephone	0.3
photocopying, shipping, postage	0.3
software : (1. Visual Basic Professional - compiler - developers edition 2. Debabelizer - image palette optimizer)	0.7
Contractual Total	$1.3

Commodities Costs:	Proposed
Description	FY 2000
office supplies	0.1
computer supplies	0.8
photographic supplies	0.2
Commodities Total	$1.1

FY 99

Prepared: 07/30/99

Project Number: 00414
Project Title: Web-based Communications Development
Name: Jennifer R. Allen
Agency: NOAA

FORM 4B
Contractual &
Commodities
DETAIL

FY 99 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
None			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage: Description	Number of Units	
Micron Windows-NT server (EVOSTC)		
Cisco routers and digital link to AK state WAN (EVOSTC)		
IBM ThinkPad 770-Z (new purchase by AK Digital Graphics)		

FY 99

Prepared: 07/30/99

Project Number: 00414
Project Title: Web-based Communications Development
Name: Jennifer R. Allen
Agency: NOAA

FORM 4B
Equipment
DETAIL

Revision 7-6-99
approved TC 8-9-99

Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators

Project Number:	00423
Restoration Category:	Research
Proposer:	J. Bodkin, D. Esler/USGS-BRD, T. Dean/CRA, Inc.
Lead Trustee Agency:	DOI
Cooperating Agencies:	None
Alaska SeaLife Center:	Yes
New or Continued:	Cont'd
Duration:	2nd yr. 4 yr. project
Cost FY 00:	$185.4
Cost FY 01:	$265.0
Cost FY 02:	$265.0
Geographic Area:	Prince William Sound
Injured Resource/Service:	Sea otter, harlequin duck

ABSTRACT

Sea otters and harlequin ducks have not fully recovered from the oil spill. This project will explore links between oil exposure and the lack of population recovery, with the intent of understanding constraints to recovery of these species and the nearshore environment. Sea otter work will include aerial surveys of distribution and abundance and estimation of abundance and size of green sea urchins. Harlequin duck work will include field and captive bird components. Field studies will examine the relationship between survival and CYP1A. Captive experiments will examine the relationships between oil exposure and CYP1A induction, and metabolic and behavioral consequences of exposure.

INTRODUCTION

The nearshore environment of Prince William Sound (PWS) received about 40% of the oil spilled after the *Exxon Valdez* ran aground (Galt et al. 1991). Concerns about nearshore recovery and restoration have resulted in a suite of studies sponsored by the Exxon Valdez Oil Spill Trustee Council, including the Nearshore Vertebrate Predator project (NVP). Principal findings of NVP include an apparent lack of population recovery for sea otters (*Enhydra lutris*) and harlequin ducks (*Histrionicus histrionicus*), both invertebrate feeders in the nearshore ecosystem. Over a three year period, harlequin ducks residing in oiled areas had poorer survival than those in unoiled areas. Although survival rates were not directly obtained for sea otters, inferences based on capture data suggest increased mortality (or higher rates of emigration) for sea otters in oiled areas compared to their counterparts in unoiled areas. Further, both species show evidence of continuing exposure to *Exxon Valdez* oil, based on higher levels of cytochrome P4501A (CYP1A) induction in oiled areas than unoiled. Elevations in CYP1A are not due to background or natural hydrocarbon sources, as these were found to be negligible in intertidal areas of PWS (Short and Babcock 1996). NVP studies also found that elevated CYP1A induction in oiled areas was not due to area differences in PCB exposure, leaving continued exposure to residual *Exxon Valdez* oil as the most plausible explanation. Residual oil is still stranded in intertidal areas of PWS (Babcock et al. 1996).

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

Sea Otters

The NVP study provided several lines of evidence indicating that sea otters in the most heavily oiled portions of western Prince William Sound (WPWS), at northern Knight and Naked islands, have not recovered from oil-related injury (Holland-Bartels et al. 1997, 1998). The sea otter population at northern Knight has not increased between 1993-98 (the period for which we have aerial survey data), with numbers remaining at about half the estimated pre-spill abundance. Demographic data suggest that reduced survival among residents and/or higher emigration from the oiled area are restricting growth of the population. Levels of CYP1A are higher in sea otters from Knight Island than from unoiled reference areas, suggesting continued exposure to residual oil may be affecting recovery of the species. Additionally, increased proportions of larger-sized individuals of several sea otter prey species were identified at northern Knight, consistent with reduced predation and lack of recovery of the sea otter population in that area.

The sea otter component of this proposal builds on previous EVOS research (93045, 95025-99025) to develop a statistically sensitive and cost-effective program that will continue to track the WPWS sea otter population and nearshore ecosystem recovery. We will address two questions: (1) are sea otters increasing in abundance in the most heavily oiled areas, and in western PWS overall?, and (2) what are the ecological interactions between sea otters and green sea urchins, a preferred invertebrate prey of sea otters?

For FY2000, we propose continued aerial surveys of sea otter abundance at appropriate intervals to monitor the population and test predictions of a previously developed sea otter population model (Restoration study 99043; Udevitz et al. 1996). We will also monitor abundance and size of intertidal green sea urchins, a key invertebrate species, which will allow an independent assessment of sea otter recovery through predicted responses in a prey population. These elements are a continuation of work proposed and approved in 1998, and initiated in Project 99423.

We propose to conduct the sea otter aerial surveys again in FY2001. In FY2002, we will conduct aerial surveys and monitor sea urchin abundance and size. The only field work planned for FY 2003 is an additional aerial survey. A final report will be prepared in FY2003 in conjunction with the harlequin duck component of the study. Information obtained from the proposed research will be valuable for monitoring recovery, or lack thereof, in the WPWS sea otter population as well as aiding our understanding of processes involved in recovery of the nearshore system to major perturbations such as the EVOS.

<u>Harlequin Ducks</u>

The most concerning result from NVP harlequin duck studies was the detection of significantly lower survival probabilities of adult females in oiled areas of PWS (76.6%) than in unoiled areas (86.6%). Analyses revealed that history of oil contamination was a more likely explanation for the survival difference than intrinsic differences between oiled and unoiled study areas. Further, projections of population trends using models incorporating these survival probabilities predicted declining populations on oiled areas and increasing populations on unoiled areas. This pattern was observed during Alaska Department of Fish and Game surveys (EVOSTC Project /427), suggesting that differences in survival were a likely mechanism for observed differences in population trends. Also, harlequin duck densities were lower on oiled Knight Island than on unoiled Montague Island, after accounting for intrinsic habitat differences; this is the pattern that would be predicted given high site fidelity and poorer survival on oiled areas. Finally, higher levels of CYP1A induction were detected on oiled areas.

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

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

NEED FOR THE PROJECT

A. Statement of Problem

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

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

Sea Otters

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

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

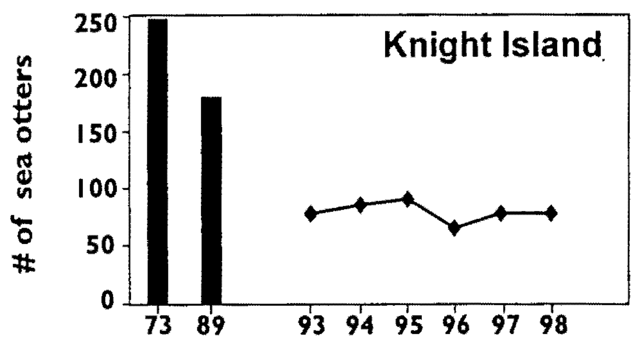

Figure 1. Estimated sea otter abundance at northern Knight Island.

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

NVP comparisons of most invertebrate prey populations between Knight Island (oiled) and Montague.Island (unoiled) identify differences in prey population structure consistent with lack of recovery of the sea otter population at the oiled site (Holland Bartels et al. 1998). At the sites where sea otter populations were greatly reduced, we have found significantly greater proportions of large individuals among most species of clams, urchins and mussels. Continued prey assessment provides a unique opportunity to complete the testing of an innovative approach for estimating the status of a predator population. When sea otter populations near complete recovery, we predict that differences in prey sizes between areas should diminish. We propose to continue monitoring the abundance of sea otters and the size and abundance of sea urchins in oiled and unoiled areas of WPWS to assess the recovery status of sea otters. These components of the proposal were approved for FY99, and will be implemented in summer 1999.

A major finding of the NVP study was elevated levels of CYP1A in 5 different species that inhabit the nearshore in oiled areas of WPWS, providing compelling evidence of continued exposure to residual EVOS oil. Sea otters were sampled in 1996-98, and in all three years, animals from Knight and Naked islands had elevated CYP1A, compared to those from the Montague study area (Table 2). Further, based on the pattern of CYP1A induction in sea otters from oiled areas (i.e., a high proportion of individuals with elevated levels in each of the three years), we can infer that exposure is generally continuous and prolonged. Sea otters from the unoiled study area have much lower CYP1A levels, similar to those measured in otters from a relatively clean area in southeast Alaska with no known exposure to oil or other contaminants. In 1998, the mean value of CYP1A in the oiled study area was lower than means for 1996 or 1997, due to the lack of any individuals with relatively high values in 1998 (see ranges in Table 2). This decline may indicate diminishing exposure to residual oil over the course of the NVP study, and continued monitoring is warranted to determine if CYP1A induction is indeed decreasing.

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

Harlequin Ducks

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

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

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

Evidence from recent studies (NVP and /427) suggests that, as might be predicted from their vulnerability, harlequin duck populations have not fully recovered and, in fact, continue to suffer deleterious effects from the oil spill. Over the course of 3 winters, survival probabilities differed between oiled and unoiled areas (Figure 2). Survival probabilities were high, and similar between areas, in fall. However, survival diverged between areas during mid-winter, presumably the period during which conditions are most difficult for harlequin ducks. Also, differences in CYP1A induction were detected between populations from oiled and unoiled areas (although this was measured on different birds than those for which survival data were collected). Further, body mass during winter showed a slight, negative relationship with CYP1A level.

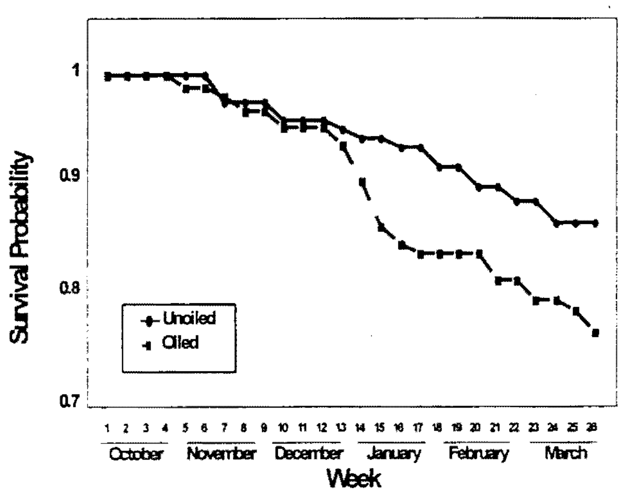

Figure 2. Survival probabilities of harlequin ducks.

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

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

B. Rationale/Link to Restoration

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

Sea Otters

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

Harlequin Ducks

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

C. Location

Studies will be conducted in PWS. Specific study sites for the sea otter components will be northern Knight Island and Port Chalmers/Stockdale at Montague Island, as used in the NVP project. Harlequin duck study sites also will be those used in previous NVP work: unoiled, Montague Island and oiled, Green Island, Crafton Island, Main Bay and Foul Bay.

Communities affected by the project include Chenega, Whittier, and Cordova.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The project will continue to inform and coordinate our community involvement activities, including the collection of indigenous knowledge with Dr. Henry Huntington, TEK specialist Chugach Regional Resources Commission and Hugh Short, Community Coordinator, EVOS Restoration Office. We will continue to solicit advice from the above parties and gather information on TEK through synthesis workshops, local community facilitators, and residents.

Efforts have and will continue to be made throughout the restoration process to participate in and provide public involvement in the design and implementation of this project. Information gathered from this project will be shared with local communities. Project staff has and will continue to present information to local communities or prepare articles or photographs for Trustee Council publications. Boat and air charter contracts, and other services will be contracted from local sources when possible.

PROJECT DESIGN

A. Objectives

<u>Sea Otters</u>

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

2. Estimate abundance and size class composition of green sea urchins in oiled and unoiled study areas.

<u>Harlequin Ducks</u>

Field Studies

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

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

Captive Bird Studies

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

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

B. Methods

Sea Otters

The proposed sea otter work employs aerial surveys to track population abundance and growth, and sampling of intertidal green sea urchins to assess sea otter-prey interactions. These approaches will provide information on recovery status of the population, assessed by growth rates and prey structuring.

Sea otter population monitoring--We will continue to use previously developed aerial survey techniques which employ counts along systematic transects, and intensive search units (ISU's) to estimate a correction factor for each survey (Bodkin and Udevitz, in press). We will conduct a single survey of the entire WPWS every two years beginning in 2000, and continue annual replicate surveys (5 or more replications per survey) of the smaller NVP study sites, beginning in 1999. In 1999, a Sound-wide survey will be conducted to provide a 5 year estimate of PWS sea otter abundance. Bi-annual WPWS surveys do not diminish our power to detect population changes in the greater WPWS area. However, increasing replicate survey intervals for the smaller NVP study areas greatly reduces our power to detect changes. It may require 8 years of annual replicate surveys (ie., 4 additional years beginning in 1999) to provide adequate power to detect a minimum of a 6% annual increase. The time required to detect this same change may extend to 12 years if the survey interval is increased to every two years (3 additional surveys). In years 2001 and 2003, additional replicates will be conducted to increase power to detect change within replicate survey areas.

Invertebrate prey population monitoring--In 1999, 2000, and 2002 (no sampling planned for 2001 or 2003) we will focus on sampling intertidal populations of green sea urchins (*Strongylocentrotus drobachiensis*). We selected this species because they are a preferred sea otter prey and have populations that are centered in the intertidal zone and can therefore be sampled efficiently, providing adequate power to detect change.

Sampling will be conducted from within Herring Bay and Bay of Isles on Knight Island, and along the Stockdale Harbor and Port Chalmers portions of Montague Island. Density estimates will be obtained from systematically selected transects along the shorelines in each area. For sea urchins, size distribution data will be supplemented by sampling in preferred sea urchin habitats. The details of site selection and sampling methods are given in Holland-Bartels et al. (1998).

Recovery of sea otter populations will be assessed by comparing the size distributions and biomass of sea urchins at Knight Island vs. Montague Island. A lack of significant differences between oiled and reference (unoiled) sites would be indicative of recovery. The data from 1999 will be combined with similar data from 1996-1998 to assess possible trends in recovery, as indicated by converging size distributions and abundances at the two sites.

Harlequin Ducks

The proposed harlequin duck work employs both field studies and experimental work with captive harlequin ducks at the Alaska SeaLife Center. This represents an ideal solution to the need for controlled work to look explicitly at the effects of oil exposure on hypothesized mechanisms of mortality and field work to document the relevance of those mechanisms under wild conditions. With captive bird studies, given the hypothesis that harlequin ducks are near an energetic threshold (i.e., do not have the capacity to increase daily energy expenditure or decrease daily energy intake), we propose quantifying metabolic and behavioral responses to known regimes of oil exposure. Also, captive studies will indicate the level of oil exposure that corresponds to CYP1A induction detected in the field. Field studies are necessary to understand the relevance of these relationships to animals in the wild, i.e., understand the link between oil exposure (as indicated by CYP1A induction) and survival probabilities. Also, field studies are required to monitor population and system recovery.

Field Studies

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

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

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

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

We will conduct radio telemetry flights at approximately weekly intervals from the capture and marking period through the end of March. Survival data entry and analysis will follow procedures outlined in Pollock et al. (1989a, 1989b), as modified by Bunck et al. (1995). In brief, we will use a Kaplan-Meier staggered entry design to estimate cumulative survival probabilities. Log rank and Z-tests will be used to compare survival functions and point estimates, respectively, between years and areas (Pollock et al. 1989a). We also will analyze survival rates using data-based models (PROGRAM MARK) that allow individual covariates such as body mass and CYP1A levels to be included in the analysis.

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

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

Captive Bird Studies

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

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

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

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

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

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

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

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

C. Cooperating Agencies, Contracts, and Other Agency Assistance

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

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

SCHEDULE

A. Measurable Project Tasks for FY00

<u>Sea Otters</u>

July: Aerial surveys of sea otters.
Sampling of intertidal green sea urchins.

<u>Harlequin Ducks</u>

April - August: Prepare for field studies (e.g., order radios, contact boat charter operators, build winter trap, contact biosample contractors, etc.).

Prepare for captive bird studies (coordinate with Alaska SeaLife Center personnel, contact aviculturists, build metabolic chamber, maintain molt trap, research appropriate dosing regime, order captive bird maintenance materials, arrange boat and air charters, etc.).

August - Sept.: Capture birds during wing molt for creation of captive flock.

Establish captive flock and initiate adjustment period.

B. Project Milestones and Endpoints

Sea Otters

FY00 (and out years):

December-March:	Coordinate and plan aerial surveys, community involvement, prepare equipment.
June-August:	Conduct aerial sea otter surveys and sea urchin surveys.
September-Nov:	Data analysis and report preparation. Coordinate with local communities.

Harlequin Ducks

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

This is a projected five-year research and monitoring program designed to assess the recovery of an injured species. Each project objective will be assessed annually for oiled and unoiled areas then compared with each other and with data collected in subsequent years. Year to year trends will first be compared in 2000 and then each year after. At the end of each year results will be compared with the restoration goals to assess whether recovery has occurred.

C. Completion Date

All project objectives will be met by FY03.

PUBLICATIONS AND REPORTS

Annual reports will be presented to the Chief Scientist by April 15. An annual report of FY00 activities will be submitted to the Restoration Office before 15 April 2001. A final report will be prepared at the end of the proposed work unless continued monitoring is warranted or when recovery objectives are met. Special reports (publications) will be prepared during the course of the study if warranted. Publications will be prepared for peer-review journals when sufficient data have been collected.

PROFESSIONAL CONFERENCES

None in FY00.

NORMAL AGENCY MANAGEMENT

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

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

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

EXPLANATION OF CHANGES IN CONTINUED PROJECTS

We initially projected a budget of $63,000 for Project 00423 in FY00, to conduct 2 components of sea otter research/monitoring (2nd year of a 5 year project): aerial surveys of sea otter distribution and abundance, and surveys of intertidal green sea urchins. Based on examination of three years of NVP data (1996-98) on harlequin ducks, we have expanded the scope of work proposed in 00423. The revised proposal includes 2 harlequin duck research and monitoring components: a captive bird study and a field study, both to examine links between oil exposure and survival rates.

A breakdown of the budget by the various project components, for FY2000, FY2001, and FY2002, is presented below (figures shown in thousands of dollars; general administration costs not included):

YEAR	SEA OTTERS	HARLEQUIN DUCKS	
	Aerial Surveys & Sea Urchin Sampling[a]	Captive Birds[b]	Field Studies[c]
FY00	58.7	52.5	24.8
FY01	44.4	95.5	121.3
FY02	60.4	77.6	121.3

[a] These components were funded in FY99 as project 99423, 1st year of a 5 year project.
Newly proposed components:

[b] Studies on captive birds at the Seward SeaLife Center (bench fees not included).
[c] Studies on wild birds to monitor CYP1A and survival.

PROPOSED PRINCIPAL INVESTIGATORS

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Revision 6-99
approved TC 8-9-99

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

Budget Category:	Authorized FY 1999	Proposed FY 2000
Personnel	$19.3	$62.9
Travel	$4.6	$7.3
Contractual	$30.8	$47.1
Commodities	$1.2	$17.6
Equipment	$0.6	$1.0
Subtotal	$56.5	$135.9
General Administration	$3.5	$12.7
Project Total	$60.0	$148.6
Full-time Equivalents (FTE)		1.1
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

		Estimated FY 2001	Estimated FY 2002		
		$286.9K	$285.9K		

Dollar amounts are shown in thousands of dollars.

Comments:

We initially projected a budget of $63,000 for Project 00423 in FY00, to conduct 2 components of sea otter research/monitoring (2nd year of a 5 year project). However, we have expanded the scope of work, and the increase in FY00 total budget over the previously projected budget is due to the addition of 2 harlequin duck research and monitoring components.

No costs are included for NEPA compliance, technical review session attendance, report writing, publications, professional conferences, or community involvement.

TOTAL PROJECT COST: $148.6
+ 36.8 ASLC bench fees
$185.4

FY00

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Agency: DOI

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2000 EXXON VALDEZ TRUSTEE 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
SEA OTTER						
J. Bodkin	Research Wildlife Biologist	GS 13-2	0.5	7.2		3.6
D. Monson	Research Wildlife Biologist	GS 9-02	4.0	4.2		16.8
						0.0
						0.0
						0.0
HARLEQUIN DUCK						
D. Esler	Research Wildlife Biologist	GS 12	4.0	6.0		24.0
K. Trust	Biologist	GS 11	1.0	5.3		5.3
Biotechnician	Biotechnician	GS 7	4.0	3.3		13.2
						0.0
						0.0
	Subtotal		13.5	26.0	0.0	
					Personnel Total	$62.9

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
SEA OTTER					
Anch/Cord/Anch	0.3	2	24	0.1	3.0
Boat transportation to Whitter	0.7	1			0.7
Field crew/gear to Whittier	0.1	2	4	0.1	0.6
					0.0
					0.0
HARLEQUIN DUCK					0.0
Esler-Seward			25	0.1	2.5
Field crew/gear to Whittier	0.5	1			0.5
					0.0
					0.0
					0.0
				Travel Total	$7.3

FY00

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Agency: DOI

FORM 3B
Personnel
& Travel
DETAIL

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

Contractual Costs:		Proposed
Description		FY 2000
SEA OTTER		
Aircraft charter 80 hrs @ 200/hr		16.0
4A Linkage Coastal Resources Associates		15.1
HARLEQUIN DUCK		
Vessel charter - late summer, capture	9 days @ 1.5	13.5
Air charter (transport birds to Seward)	10 hours @ $250	2.5
When a non-trustee organization is used, the form 4A is required.	**Contractual Total**	$47.1

Commodities Costs:		Proposed
Description		FY 2000
SEA OTTER		
Miscellaneous field/office supplies		1.5
Fuel		0.4
HARLEQUIN DUCK		
Kayak rental	6 @ $150	0.9
Molt trap maintenance		0.5
Captive flock maintenance	1 month @ $450	0.5
Metabolic chamber materials		1.0
Winter trap materials		1.5
Radio transmitters	50 @ $225	11.3
	Commodities Total	$17.6

FY00

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Agency: DOI

FORM 3B
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
SEA OTTER			
Equipment maintenance and repair			1.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$1.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency

FY00

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Agency: DOI

FORM 3B
Equipment
DETAIL

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

Budget Category:	Authorized FY 1999	Proposed FY 2000
Personnel		$7.2
Travel		$0.9
Contractual		$0.0
Commodities		$0.5
Equipment		$0.0
Subtotal	$0.0	$8.6
Indirect		$6.5
Project Total	$0.0	$15.1
Full-time Equivalents (FTE)		0.1
Other Resources		

LONG RANGE FUNDING REQUIREMENTS

		Estimated FY 2001	Estimated FY 2002		
		$0.0	$16.0		

Dollar amounts are shown in thousands of dollars.

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

No overhead or fees are charged on contractual costs

FY00

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Name: Thomas A. Dean - Coastal Resources Associates, Inc.

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
T. Dean	Biologist		0.7	8.1		5.7
D. Jung	Biologist		0.4	3.7		1.5
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		1.1	11.8	0.0	
					Personnel Total	$7.2

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
San Diego/Anch/SanDiego	0.6	1	3	0.1	0.9
(attend EVOS Annual Workshop)					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$0.9

FY00

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Name: Thomas A. Dean - Coastal Resources Associates, Inc.

FORM 4B
Personnel
& Travel
DETAIL

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

Contractual Costs:	Proposed
Description	FY 2000
Contractual Total	$0.0

Commodities Costs:	Proposed
Description	FY 2000
Miscellaneous field supplies	0.5
Commodities Total	$0.5

FY00

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Name: Thomas A. Dean - Coastal Resources Associates, Inc.

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
			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

Prepared: 6 July 99

Project Number: 00423
Project Title: Patterns and Processes of Population Change in Selected Nearshore Vertebrate Predators
Name: Thomas A. Dean - Coastal Resources Associates, Inc.

FORM 4B
Equipment
DETAIL

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$34.4						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$34.4			Estimated FY 2001	Estimated FY 2002		
General Administration		$2.4						
Project Total	$0.0	$36.8						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Project Number: 00423
Project Title: Population Change in Selected Nearshore Vertebrate Predators -- ASLC Bench Fee Component
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

00424

approved TC 8-9-99

Exxon Valdez Oil Spill Restoration Reserve

Project Number:	00424
Restoration Category:	Restoration Reserve
Proposer:	All Trustee agencies
Duration:	Ongoing
Cost FY 00:	$12,000,000
Cost FY 01:	$12,000,000
Cost FY 02:	$12,000,000
Geographic Area:	Oil spill area
Injured Resource/Service:	Multiple resources and services

ABSTRACT

In recognition of the fact that complete recovery from the oil spill may not occur for decades, the Trustee Council established the Restoration Reserve to hold funds to be used for restoration after the last annual payment is received from the Exxon Corporation in September 2001. The $12 million recommended for deposit in FY 00 would be the seventh deposit into the reserve account, and would bring the total in the account to $84 million. Annual deposits of $12 million in each of the next 2 years would provide a reserve of $108 million plus interest (roughly $170 million). On March 1, 1999 the Council approved a spending plan for the future use of these funds.

INTRODUCTION

In recognition of the fact that complete recovery from the oil spill may not occur for decades, the Trustee Council established the Restoration Reserve to hold funds to be used for restoration after the last payment is received from Exxon Corporation in September 2001. The Reserve will operate as an endowment, with annual earnings on $115 million to be spent on a long-term research and monitoring program and annual earnings on $55 million to be spent on habitat protection.

NEED FOR THE PROJECT

A. Statement of Problem

The Chief Scientist and other investigators working on the restoration program have identified a need to maintain restoration activities in the years following Exxon's last scheduled payment in the year 2001. The collection of long-term data sets is increasingly recognized as essential to understanding the results from any single year. In addition, there continues to be strong public interest in the Trustee Council's large and small parcel habitat protection efforts.

B. Rationale/Link to Restoration

To be effective, restoration activities may have to span more than one generation. For example, some salmon return in cycles of four to six years while other resources have lives that are much longer. In addition, oceanographic influences on the health and survival of numerous injured species under investigation are only just beginning to be understood. Work under the major ecosystem studies (SEA, NVP, APEX), while providing significant new insight into the status of recovery and health in the spill area, is also bringing attention to new questions that may require continuing efforts long into the future. This includes the identification of key areas or times of year (spatial or temporal refuges) and processes critical to the long-term recovery of injured resources and associated services.

C. Location

Oil spill area.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The Restoration Office conducted a series of public meetings to provide opportunity for comment on possible future uses of the Restoration Reserve including public meetings in communities throughout the spill impacted region and also in Anchorage, Fairbanks and Juneau. Community involvement and TEK will continue to be integral components of any long-term restoration program.

PROJECT DESIGN

A. Objectives

The essential objective of the Restoration Reserve is to ensure that funds are available to support restoration activities beyond the end of the settlement payment period.

B. Methods

This proposed $12 million would be the seventh payment to the Restoration Reserve. Based on previous Trustee Council action, the total principal after this deposit would be $84 million. Additional annual deposits of $12 million in each of the remaining two years would provide a reserve of $108 million plus interest earned by investment of these funds (with other unexpended funds, roughly $170 million). This amount is expected to be sufficient to carry out long-term restoration activities after the last Exxon payment in the year 2001. Funds in the Restoration Reserve are currently invested in laddered securities within the Court Registry Investment System; accrued earnings remain with the Restoration Reserve. Other options for investment are currently being researched.

Any spending from the Restoration Reserve must be consistent with the Consent Decree and with the Memorandum of Understanding between the state and federal governments.

C. Cooperating Agencies, Contracts and Other Agency Assistance

Not applicable.

SCHEDULE

A. Measurable Project Tasks for FY 00

The $12 million transfer for FY 00 will be transferred from the Court Registry Investment System Liquidity Fund to the Restoration Reserve Fund by court order when such funds are available.

B. Project Milestones and End Points

This project will be complete when the funds are transferred from the Court Registry Investment System Liquidity Fund to the Restoration Reserve Fund by court order.

C. Completion Date

The project (i.e., the annual deposit of $12 million) will have been completed at the end of the fiscal year.

PUBLICATIONS AND REPORTS

Not applicable.

PROFESSIONAL CONFERENCES

Not applicable.

NORMAL AGENCY MANAGEMENT

Not applicable.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Not applicable.

EXPLANATION OF CHANGES IN CONTINUING PROJECTS

Not applicable.

PROPOSED PRINCIPAL INVESTIGATOR

Molly McCammon
Executive Director
Exxon Valdez Oil Spill Trustee Council
645 G Street
Anchorage, Alaska 99517
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approved TL 8-9-99

Harbor Seal Recovery: Effects of Diet on Lipid Metabolism and Health

Project Number:	00441
Restoration Category:	Research
Proposer:	R. Davis/Texas A&M Univ.
Lead Trustee Agency:	ADFG
Cooperating Agencies:	None
Alaska SeaLife Center:	Yes
New or Continued:	Cont'd
Duration:	2nd yr. 3 yr. project
Cost FY 00:	$191.6
Cost FY 01:	$78.1
Cost FY 02:	$0.0
Geographic Area:	Prince William Sound and Alaska SeaLife Center
Injured Resource/Service:	Harbor seals

ABSTRACT

Changes in food availability could be affecting harbor seal population recovery. To better understand the results from field studies of harbor seal health, body condition and feeding ecology, data is needed for seals on diets that vary in nutritional composition. Working with the Alaska SeaLife Center, this project will determine how fatty acid profiles in the blubber of captive harbor seals change over time during controlled diets of herring and pollock. In addition, the project will assess the aerobic capacity and lipid metabolism of skeletal muscle in harbor seals fed controlled diets and in wild harbor seals in Prince William Sound. The results will enhance understanding of the nutritional role and assessment of dietary fat for harbor seals.

ACCOMPLISHMENTS FOR THE FIRST HALF OF YEAR ONE (SEPT. TO MAY 1999)

Feeding trials for eight harbor seals began in early September 1998 at the Alaska SeaLife Center. Four seals received a diet of herring and four a diet of pollock. Midway through the trial, blubber samples only were taken at two sites from each seal. At the end of this feeding trial (January 12), blubber and muscle biopsies were taken from two sites on each animal. Half of each muscle sample was placed in fixative, and the remainder along with the blubber samples were frozen at –70° C. The muscle samples were shipped to the University of California at San Diego where analysis (% fiber type, volume density of lipid droplets and mitochondria, lipid enzyme activities, and myoglobin concentration) is underway. The blubber samples will be analyzed for fatty acid profiles at Texas A&M University. This first feeding trial and the biopsies were completely successful. The second feeding trial is underway, and another series of biopsies will be taken in May 1999. No significant problems have been experienced, and we are on schedule. Preparations have been made for obtaining blubber and muscle samples from wild harbor seals in Prince William Sound as part of the BIOSAMPLING Program in June 1999.

INTRODUCTION

Understanding the feeding ecology and nutritional status of harbor seals (*Phoca vitulina richardsi*) is an essential component of ecosystem-based research on the recovery of species impacted by the Exxon Valdez oil spill in Prince William Sound. Until recently, determinations of prey preferences for pinnipeds have been based on stomach content and fecal analyses, both of which can only yield information on the most recent meals and may be biased due to differential rates of passage of food items. A new technique using fatty acid profiles of blubber can provide details on cumulative dietary history. It can also, in some cases, be used to determine foraging habitat. In pinnipeds, as with other carnivores and monogastric animals, dietary fatty acids generally remain intact through the digestion process and are deposited in adipose tissue with little or no modification (1). As a result, differences in the fatty acid composition of carnivore blubber can be used to infer dietary differences between individuals or populations and perhaps even species composition of the diet.

Previous research has shown that fatty acid signatures are significantly affected by spatial or temporal heterogeneity in habitat and food webs (1). In a study of harbor seal foraging ecology (Project 117-BAA; Harbor seal blubber and lipids) supported by the Restoration Program, Iverson, et al (2) were able to distinguish individual species of fish using fatty acid signatures. They also found fatty acid composition of these prey items to be correlated with body size as well as location within a study area. Hence, analysis of fatty acids in pinnipeds and their prey should provide details on the spatial scales of foraging and habitat use of both individuals and populations. Evaluating how harbor seal blubber fatty acids change with diet during controlled feeding studies where species composition of diet is known will improve the spatial and temporal interpretation of fatty acid profiles of wild seals whose diet composition is unknown.

Muscle condition and metabolic function can be used as indicators of the health status of marine mammals. Important indices of muscle function and health are aerobic capacity, the ability to store oxygen in the form of oxy-myoglobin and the size of lipid stores. In a preliminary study conducted by our laboratory (3), we observed that the volume density of mitochondria, myoglobin concentration and citrate synthase activity in the swimming muscles of harbor seals were elevated relative to terrestrial mammals and appeared to be an adaptation for aerobic metabolism during diving. One objective of this study is to study the effect of diet on the aerobic capacity, myoglobin concentration and lipid stores of skeletal muscles in harbor seals. In addition, we will measure the activities of citrate synthase and *B*-hydroxyacyl CoA dehydrogenase (an enzyme important for lipid metabolism) as indicators of aerobic capacity and the *B*-oxidation of fatty acids, respectively.

The Restoration Program has supported the population monitoring component of health assessment, diving behavior and food preferences of harbor seals in Prince William Sound. Now, with controlled feeding studies of harbor seals underway at the Alaska SeaLife Center, we will continue our studies of the effects of diet on fatty acid signatures in blubber and the metabolic function of muscle, especially with regards to lipid. The results will improve our understanding of harbor seal feeding ecology and the effects of diet on health and metabolism.

NEED FOR THE PROJECT

A. Statement of Problem

The Restoration Program has supported three harbor seal studies in Prince William Sound (Project 001- Harbor seal condition and health status; Project 064- Monitoring habitat use and trophic interactions of harbor seals; Project 117-BAA- Harbor seal blubber and lipids). One objective of these studies has been to measure health and body condition indices related to metabolic alterations that might occur in animals that were food deprived. Although these studies collected much useful information, some researchers realized that controlled dietary studies were needed to more completely interpret field data. In 1997, the Restoration Program funded a captive study (Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet) at the Alaska SeaLife Center that will quantify the nutritional value of several key Alaskan fish species for harbor seals and will follow health indices over time in both healthy and rehabilitation animals. That project, which has been underway at the ALASKA SEALIFE CENTER for six months, will feed controlled diets of fish to harbor seals to examine changes in body condition, health, assimilation efficiency and blood chemistry biomarkers. Of particular interest will be the health and body condition effects of diets containing nutritionally poor (compared to herring) fish such as pollock, the so-called "junk food" hypothesis for explaining the decline of certain pinniped stocks. In the proposed research, we will continue (one feeding Trial is completed and the second will be completed in May 1999) to take advantage of the controlled feeding studies at the ALASKA SEALIFE CENTER to examine the effects of diet on: 1) fatty acid markers in the blubber, 2) muscle condition and 3) lipid metabolism. In addition, we will use samples of blubber and muscle obtained by the BIOSAMPLING Program in Prince William Sound for comparison with captive seals fed known diets. This important work will augment already funded investigations of diet and health to provide a more in depth understanding of the nutritional role and assessment of dietary fat for harbor seals.

B. Rationale

The harbor seal population in Prince William Sound has not recovered and may continue to decline. An underlying hypothesis is that ecosystem wide changes in food availability could be affecting harbor seal population recovery. To better understand the behavioral and physiological results obtained from field studies of harbor seal health, body condition and feeding ecology supported by the Restoration Program, we need comparable data for seals on diets that vary in nutritional composition. In 1998, a captive study was begun at the ALASKA SEALIFE CENTER to quantify the health effects of feeding several key Alaskan fish species to harbor seals. We propose to augment this study by examining changes in fatty acid profiles in seal blubber and muscle lipid content during controlled feeding studies where fish species composition is known. In addition, we will quantify the aerobic capacity and activities of enzymes that are crucial for muscle lipid metabolism and which may be affected by nutritional stress.

C. Location

The experiments for this project will be conducted at the Alaska SeaLife Center in Seward. We will collaborate with existing projects that will examine the detailed metabolic alternations in stable isotope ratios (Schell/Project 170) and changes in body condition and health indices (Castellini/Project 341) in harbor seals that occur under different feeding regimes.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Native communities have assisted Field studies of harbor seals in conjunction with the BIOSAMPLING program (Project 96244). We will continue that collaboration by analyzing samples of muscle, blubber and other tissues taken as part of subsistence hunting

PROJECT DESIGN

A. Objectives

1. Determine how fatty acids in the blubber of captive harbor seals change over time during controlled diets of herring and pollock.

2. Measure the content and composition of lipid in muscle of captive harbor seals fed controlled diets and for wild harbor seals in Prince William Sound.

3. Assess the aerobic capacity and lipid metabolism of skeletal muscle in harbor seals fed controlled diets and for wild harbor seals in Prince William Sound.

B. Methods

1. Hypotheses to be Tested.

1. Null hypothesis: Fatty acid profiles in the blubber of harbor seals are not affected by the fatty acid composition of the diet.

   Alternative hypothesis: Fatty acid profiles in the blubber of harbor seals will be directly affected by the fatty acid composition of the diet and will change as the diet is altered.

   Methodology: Feed controlled diets of different fish species to captive harbor seals. Assess temporal changes in the fatty acid composition of the blubber by taking serial biopsies. Compare with samples obtained from the BIOSAMPLING program of wild harbor seals in Prince William Sound.

2. Null hypothesis: Mitochondrial volume density, myoglobin concentration, lipid content, and the enzymatic activities of citrate synthase and *B*-hydroxyacyl CoA dehydrogenase are not affected by diet.

   Alternative hypothesis: These variables of muscle condition and function are affected by changes in diet.

   Methodology: Feed controlled diets of different fish species to captive harbor seals. Assess temporal changes in these variables by taking serial muscle biopsies. Compare with samples obtained from the BIOSAMPLING program of wild harbor seals in Prince William Sound.

2. Harbor Seal Feeding Trials Conducted at the Alaska SeaLife Center (ASLC).

Animals. Eight harbor seals have been acquired by the ASLC for the feeding trials that began in September 1998. Dr. Michael Castellini (Research Director at ASLC) developed dietary protocols for EVOS Project 99341. During the staggered feeding trials, the diet will be changed every four months. During these dietary manipulations, we will obtain serial blubber samples every two months and muscle biopsies every four months from two sites on each animal.

Design for Feeding Trials. A detailed matrix of the feeding schedule developed by Dr. Castellini is shown below. The procedure will use a cross-over repeated measures approach and will allow statistical comparisons within any one group of seals between diet and season. Statistical software (SYSTAT) will be used to analyze the cross-over method. However, there are several considerations that must be addressed using this matrix.

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-April 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-April 2000	A,B,C	D,E,F	Spring
May-Aug 2000	D,E,F	A,B,C	Breeding

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, will receive a herring diet during the molting season in Year 1 and a high pollock diet in Year 2. After training during the summer of 1998, the seals accepted a pollock diet that was 75-80% pollock.

A problem with cross-over ANOVA designs is that residual or carry-over effects from previous treatments can complicate the analysis. We correct for this with 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 impact of the phased switch on blubber and muscle lipid content and composition, and on muscle lipid metabolism.

Blubber Biopsies. Blubber samples will be obtained through the full depth of blubber layer with a 6-mm punch biopsy inserted through a small incision in the skin. Samples will be immediately transferred to liquid nitrogen and stored at -70° C until analysis. Total lipids will be extracted in chloroform according to Folch et al. (4) as modified by Iverson (5). Fatty acid methyl esters (FAME) will be prepared from the purified lipid extracts using the Hilditch reagent (0.5 N H_2SO_4 in methanol). FAME for fish in the controlled diets will be obtained similarly from homogenates of individual food items. The methyl esters will be analyzed by temperature-programmed capillary gas-liquid chromatography. FAME will be identified and quantified using a combination of standard mixtures, including those identified using chromatography and an ion-trap mass detector. Individual fatty acids, expressed as weight percent of the total fatty acids, will be analyzed using classification and regression trees (CART) in S-plus (StatSci, Seattle), a non-parametric multivariate technique for classifying data. CART uses a series of algorithms to split data into groups as differently as possible, based on measures of deviance; the splitting continues in a tree-like form until a classification is made at a terminal node. The analysis of blubber fatty acids is already being conducted in our laboratory in collaboration with Dr. Sara Iverson (University of Halifax) as part of a feeding ecology study of Steller sea lions. This collaboration will continue during the proposed harbor seal study.

Muscle Biopsies. Two muscle samples of approximately 50 mg each will be collected with a 6 mm biopsy cannula (Depuy, Warsaw, Indiana) from both the swimming (*M. longissimus dorsi*) and non-swimming (*M. pectoralis*) muscles. Control samples will be collected from the *M. soleus*, a predominantly slow oxidative muscle, of laboratory rats (*Sprague Dawley*) euthanized by cervical dislocation after 2-3 min of carbon dioxide anesthesia. Muscle samples will be placed either into 2% glutaraldehyde fixative or frozen in liquid nitrogen immediately upon collection. Samples will remain in the fixative for a minimum of 48 hours but no longer then 14 days before being transferred and stored in 0.1 M cacodylate buffer pH 7.4. Frozen samples will be stored at -70 °C until analysis for citrate synthase activity, *B*-hydroxyacyl CoA dehydrogenase activity and myoglobin concentration.

Electron Microscopy of Muscle Samples. Fixed muscle samples will be rinsed in cacodylate buffer and post-fixed for 2 hours in a 1% solution of osmium tetra oxide. They will be stained 'en bloc' with 2% uranyl acetate overnight in a refrigerator. After dehydration with increasing concentrations of ethanol (50-100%), they will be passed through propylene oxide and increasing concentrations of epoxy (50-100%). The samples are finally embedded in fresh epoxy and allowed to polymerize overnight at 60 ° C. Thick sections (1 mm) will be cut with a Leica Ultratome and stained with toulidine blue to determine fiber orientation. Ultrathin (50-70 nm), transverse sections will be cut and contrasted with lead citrate from 4 randomly chosen blocks per muscle. Micrographs will be taken with a Phillips 201 transmission electron microscope. The number of micrographs per muscle analyzed will range from 25 and 40, yielding relative standard errors of less than 10% in all muscles. Determination of the volume density of mitochondria, myofibrils and lipid droplets will be performed at a final magnification of x19,250 using standard point counting procedures (6, 7). The electron microscopy will be conducted under the supervision of Dr. Odile Mathieu-Costello at the University of California at San Diego (see attached letter).

Citrate Synthase, B-hydroxyacyl CoA dehydrogenase and Myoglobin Assays of Muscle Samples. Frozen muscle samples will be weighed and then homogenized at 0° C in 1 ml of buffer containing 1 mmol L^{-1} EDTA, 2 mmol L^{-1} $MgCl_2$, and 75 mmol L^{-1} Tris-HCl, pH 7.6 at 25 ° C (8). The homogenates will be spun at 2,900 g for 30 minutes at 4° C. 500 ml from each supernatant will be prepared for myoglobin assay and the rest will be used for the analysis of citrate synthase. Citrate synthase and *B*-hydroxyacyl CoA dehydrogenase will be assayed on a Beckman DU series 64 spectrophotometer according to the method of Reed et al. (1994). Assay temperature will be maintained at 37 ° C using a constant temperature water bath and a water-jacketed cuvette holder. The assay conditions for citrate synthase (CS; EC 4.1.3.7) will be 50 mmol L^{-1} imidazole, 0.25 mmol L^{-1} 5,5-dithiobis (nitrobenzoic acid, DTNB), 0.4 mmol L^{-1} acetyl CoA, and 0.5 mmol L^{-1} oxaloacetate, at pH 7.5; $DA_{412}, e_{412} = 13.6$ (8). For *B*-hydroxyacyl CoA dehydrogenase (HAD; EC 1.1.1.35), the assay conditions will be 50 mmol L^{-1} imidazole, 1 mmol L^{-1} EDTA, 0.1 mmol L^{-1} acetoacetyl CoA, and 0.15 mmol L^{-1} NADH, pH 7.0 at 37° C; $DA_{340}, e_{340} = 6.22$ (9). Enzyme activities (mmol min^{-1} g^{-1} wet mass muscle) will be calculated from the rate of change in absorbance at the maximum linear slope. Myoglobin will be assayed according to the method of Reynarfarje (1963) with the following modifications. A portion (500 ml) of the supernatant is further diluted with 1 ml of phosphate buffer (0.04 M, pH 6.6). The resulting mixture is centrifuged for 50 min at 28,000 g at 4°C. The supernatant is bubbled with carbon monoxide for three min. Spectrophotometric absorbance will be measured at 538 and 568 nm, and the concentration of myoglobin in milligrams g^{-1} wet mass of muscle will be calculated as:

$$(Abs_{538} - Abs_{568}) \times 5.865 [(1.5/0.5) \times (\text{mass of sample})]$$

Statistical Analysis. Results will be expressed as the mean ± one standard error. We will use a cross-over repeated measures approach that will allow statistical comparisons within any one group of seals between diet and season. Statistical software (SYSTAT) will be used to analyze the cross-over method. The relative proportions of fatty acids from blubber samples of seals in the controlled feeding study will be used as a basis for generating tree-based models (using S-Plus; StatSci, Seattle) of groups or classes of samples such that new samples (obtained via BIOSAMPLING) can be compared with the modeled classes to decide their membership, i.e. obtain a classification of their "diet". Similarly, classification and regression trees will be used to screen the set of prey fatty acids and choose a subset of those fatty acids which can be used to classify the "diets" of seals based the patterns of fatty acid proportions in their blubber.

3. Blubber and Muscle Samples Obtained from the BIOSAMPLING Program in Prince William Sound.

The main swimming muscle of 10 harbor seals will be obtained during BIOSAMPLING Program. The entire muscle will be removed and weighed, and three transverse sub-samples will be taken along the muscle bundle. Each sub-sample of the swimming muscle will be precisely labeled for its orientation and location within the animal. These will then be further sub-sampled along points on a circular grid using a stainless steel borer, averaging 35 samples per muscle section. Cores of tissues weighing 200 and 300 mg will be removed for assay. A spectrophotometric technique will be used to determine myoglobin, citrate synthase, and *B*-hydroxyacyl CoA dehydrogenase concentration (see above for details). Detailed contour maps and statistical tests for all concentrations will be made using a PC based program S-Plus (Stat-Sci, Seattle). Blubber samples will also be obtained from the same approximate anatomical location as on animals used in the captive studies and stored frozen at -70 °C. Blubber samples will be analyzed according to the protocols described in Section 2 of this proposal.

SCHEDULE

A. Measurable Project Tasks for FY 99 (October 1, 1998 - September 30, 1999), FY 00 (October 1, 1999 - September 30, 2000) and FY 01 (October 1, 2000 - March 31, 2001)

Each feeding trial will take four months beginning in September, 1998.

1998	
September	Set up fatty acid analysis and muscle lipid and enzyme analysis
September-December	Trial 1 of staggered feeding protocol at ASLC. Obtain and analyze blubber and muscle biopsies. Status- completed on schedule.
1999	
January-April	Trial 2 of staggered feeding protocol. Obtain and analyze blubber and muscle samples. Status- underway and on schedule.

May-August	Trial 3 of staggered feeding protocol. Obtain and analyze blubber and muscle samples. Status- on schedule. Obtain blubber and muscle samples from wild harbor seals in Prince William Sound in conjunction with BIOSAMPLING Program. Status- planning is completed; field work will begin in June 1999.
September-December	Trial 4 of staggered feeding protocol at ASLC. Obtain and analyze blubber and muscle biopsies.
2000	
January-April	Trial 5 of staggered feeding protocol. Obtain and analyze blubber and muscle samples.
May-August	Trial 6 of staggered feeding protocol. Obtain and analyze blubber and muscle samples. Obtain blubber and muscle samples from wild harbor seals in Prince William Sound in conjunction with BIOSAMPLING Program.
September-December	Analyze data and begin preparation of Final Report and manuscripts
2001	
December-March	Complete Final Report and submit manuscripts. Two manuscripts are anticipated at this time.

Note: Samples will be analyzed in groups as they are received. For the fatty acid analysis, it is most efficient to analyze the samples from every two feeding Trials.

B. Project Milestones

FY 99: Obtain and analyze blubber and muscle samples during feeding studies at ASLC. Complete analysis of muscle and blubber samples from first four feeding Trials and the BIOSAMPLING Program in Prince William Sound.

FY 00: Continue to obtain and analyze blubber and muscle samples during feeding studies at ASLC; obtain and analyze blubber and muscle samples from seals in Prince William Sound in conjunction with BIOSAMPLING Program; analyze all data; begin preparation of Final Report and manuscripts.

FY 01 Complete Final Report and manuscripts by March.

C. Completion Date

This project will finish on March 31, 2001.

PUBLICATIONS AND REPORTS

Since this is a new project, there are no current publications from the proposed research. However, the results from a preliminary study of the aerobic capacity and lipid content of muscles from harbor seals in Prince William Sound will be published in the Journal of Applied Physiology in April 1999. We do not anticipate any referred articles in FY 99. However, by FY 2000 most of the data will be analyzed and manuscripts in preparation. Because samples will continue to be collected through August 2000, we request an additional six month (Sept. 2000 to March 2001) to complete data analysis and prepare the Final Report and manuscripts. We anticipate at least two publications by 2001 on the effects of diet on fatty acids in blubber and the aerobic capacity and lipid metabolism in harbor seal muscle.

PROFESSIONAL CONFERENCES

The PI requests funds to attend the annual EVOS workshops each year.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

We are working in close coordination with Dr. Michael Castellini (PI on Harbor Seal Recovery. Phase II: Controlled Studies of Health and Diet) and staff at the Alaska SeaLife Center (see attached letter). Dr. Castellini is supervising the controlled diet studies. We have coordinated our blubber and muscle samples with the veterinary staff at ASLC. Samples obtained from the BIOSAMPLING program will be coordinated with Ms. Monica Riedel of the Alaska Native Harbor Seal Commission.

PROPOSED PRINCIPAL INVESTIGATOR

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PRINCIPAL INVESTIGATOR

Randall Davis, Ph.D., specializes in the physiology and metabolism of marine mammals. He is a Professor of Marine Biology at Texas A&M University and has worked in this field for over 20 years. In 1989, Dr. Davis was the Project Leader for Exxon's Oiled Sea Otter Rehabilitation Program in Prince William Sound.

Revised Feeding Regime

2. Harbor Seal Feeding Trials Conducted at the Alaska SeaLife Center (ASLC).

Animals. Eight harbor seals have been acquired by the ASLC for the feeding trials. Dietary protocols have been developed by Dr. Michael Castellini (Research Director at ASLC) for EVOS Project 99341. In the event that our proposed study is funded, Dr. Castellini has already agreed to obtain blubber and muscle biopsies from the seals during the controlled phase (herring only) of the dietary studies during the summer 1998. Beginning in FY99, we would begin direct participation in the feeding studies. During the staggered feeding trials, the diet will be changed every four months. During these dietary manipulations, we will obtain serial blubber and muscle biopsies of not less than once per month from two sites on each animal.

Design for Feeding Trials. A detailed matrix of the feeding schedule has been developed by Dr. Castellini and is shown below. The procedure will use a cross-over repeated measures approach and will allow statistical comparisons within any one group of seals between diet and season. Statistical software (SYSTAT) will be used to analyze the cross-over method. However, there are several considerations that must be addressed using this matrix.

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-April 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-April 2000	A,B,C	D,E,F	Spring
May-Aug 2000	D,E,F	A,B,C	Breeding

Two seals (G,H) will be in a separate feeding trial. They will follow alternating four month periods of herring and pollock, but for these animals feeding frequency and total mass fed will be varied every two weeks. For these two animals, blubber biopsy samples will be obtained at the end of each two week feeding period. Since the biopsies are small (see below), this should not affect the animals' health.

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, will receive a herring diet during the molting season in Year 1 and a high pollock diet in Year 2. We will work during the summer of 1998 to establish the highest amount of pollock in a diet that will be accepted by the animals. We expect this to be at least 75-80% pollock.

A problem with cross-over ANOVA designs is that residual or carry-over effects from previous treatments can complicate the analysis. We correct for this with 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 impact of the phased switch on blubber and muscle lipid content and composition, and on muscle lipid metabolism.

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

approved TC 8-9-99

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$123.0						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$123.0			Estimated FY 2001	Estimated FY 2002		
General Administration		$8.6						
Project Total	$0.0	$131.6			$78.1			
Full-time Equivalents (FTE)		1.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

TOTAL PROJECT COST: $131.6
\+ 60.0 ASLC bench fees
$191.6

FY00	Project Number: 00441 Project Title: Harbor Seal Recovery Phase III: Effects of Diet on Lipid Metabolism and Health Agency: Alaska Department of Fish and Game	FORM 3A TRUSTEE AGENCY SUMMARY

Prepared:

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$47.5						
Travel		$21.2						
Contractual		$5.3						
Commodities		$10.8						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$84.8			Estimated FY 2001	Estimated FY 2002		
Indirect @ 45% ($84,828)		$38.2						
Project Total	$0.0	$123.0			$73.0			
Full-time Equivalents (FTE)		1.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

Indirect Costs @ 45% of Modified Total Direct Cost. The indirect cost rate is a predetermined rate established by the Department of Health and Human Services dated 9/9/97.

Fringes are calculated @ 15.5% of Salaries and Wages for the Pricnipal Investigator and Research Assistant. 8.25% is the calculation for the Graduate Research Assistant. Included in the fringe category is a fixed rate for medical insurance. The rate is a calculation based on the percentage of effort. The Principal Investigator is calculated @ $370/mo. The Research Assistant and Graduate Research Assistant is calculated @ $298/mo.

FY00

Prepared:

Project Number: 00441
Project Title: Harbor Seal Recovery Phase III: Effects of Diet on Lipid Metabolism and Health
Name: Texas A&M Research Foundation

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
R. Davis	Principal Investigator		3.0	8411.6		25,235.0
Vacant	Research Assistant		6.0	2182.5		13,095.0
Vacant	Graduate Research Assistant		3.0	3066.0		9,198.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		12.0	13660.1	0.0	
					Personnel Total	$47.5

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
To Seaward, Alaska for research at Alaska SeaLife Center (4 people)	1200.0	4	120	100.0	16,800.0
Car Rental in Seaward, Alaska	40.0	30			1,200.0
To Anchorage, Alaska for EVOS workshop	1200.0	1	5	100.0	1,700.0
To Halifax, Canada for gas chromatograph analysis	1000.0	1	5	100.0	1,500.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$21.2

FY00

Prepared:

Project Number: 00441
Project Title: Harbor Seal Recovery Phase III: Effects of Diet on Lipid Metabolism and Health
Name: Texas A&M Research Foundation

FORM 4B
Personnel
& Travel
DETAIL

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

Contractual Costs:	Proposed
Description	FY 2000
Gas Chromatograph analysis (To Be Named)	2,500.0
Electron Microscope analysis (University of California, San Diego)	2,500.0
Communications - Long Distance Telephone Charges	300.0
Contractual Total	**$5.3**

Commodities Costs:	Proposed
Description	FY 2000
Expendable supplies and chemicals	10,000.0
Shipping of blood for analysis	300.0
Publication and Page Charges	500.0
Commodities Total	**$10.8**

FY00

Project Number: 00441
Project Title: Harbor Seal Recovery Phase III: Effects of Diet on Lipid Metabolism and Health
Name: Texas A&M Research Foundation

FORM 4B
Contractual & Commodities
DETAIL

Prepared:

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

Existing Equipment Usage: Description	Number of Units	

FY00

Prepared:

Project Number: 00441
Project Title: Harbor Seal Recovery Phase III: Effects of Diet On Lipid Metabolism and Health
Name: Texas A&M Research Foundation

FORM 4B
Equipment
DETAIL

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$56.1						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$56.1			Estimated FY 2001	Estimated FY 2002		
General Administration		$3.9						
Project Total	$0.0	$60.0						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Project Number: 00441
Project Title: Harbor Seal: Effects of Diet on Lipid Metabolism and Health -- ASLC Bench Fee Component
Agency: ADFG

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Revision 7-8-99
approved TC 8-9-99

Evidence and Consequences of Persistent Oil Contamination in Pink Salmon Natal Habitats

Project Number:	00454
Restoration Category:	Research
Proposer:	S. Rice/NOAA
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	New
Duration:	1st yr. 2 yr. project
Cost FY 00:	$334.1
Cost FY 01:	$104.0
Cost FY 02:	$0.0
Geographic Area:	Prince William Sound, Little Port Walter
Injured Resource/Service:	Pink salmon

ABSTRACT

This project will (a) examine the natal habitat of pink salmon in Prince William Sound for evidence of oil contamination in eggs and spawning redds, (b) measure cytochrome P4501A in field and laboratory exposed alevins to relate induction with biological consequences on growth and survival following PAH exposure, and (c) synthesize these results with past research and a reexamination of the recovery status of pink salmon and their spawning habitat. A combination of field and laboratory studies will be conducted for one year to complete the pink salmon toxicity story. Persistent oil reservoirs adjacent to natal streams will be reexamined for evidence of habitat recovery, and the hypothetical mechanism of hydrocarbon introduction into the streams (transfer of dissolved oil in pore water) will be quantified by use of collectors (SPMDs) buried in spawning habitat. The biomarker cytochrome P4501A will be measured in eggs and alevins from field and controlled laboratory exposures. The significance of the biomarker will be determined in measurements of marine growth and survival, using fish from brood year 1998 tests underway.

INTRODUCTION

The recovery status of pink salmon in Prince William Sound (PWS) is problematic, because population levels as a whole are relatively high and include fish from large areas with little or no oil-exposure history), while the banks of specific natal streams remain contaminated with oil (Murphy et al. In press). Part per billion sensitivities to oil have been documented in early life stages (Heintz et al. 1999), and elevated egg mortalities in oiled streams were reported by ADF&G as late as 1997. Recovery at the stream level is unknown, and the definition of recovery for pink salmon needs to be re-examined. This proposal will "close the loop" on past pink salmon oil toxicity research by examining the status of oil contamination and egg/alevin exposure at oiled benchmark streams. The use of the biomarker P4501A will be used in field and laboratory tests, and the biological significance of the biomarker will be determined in short-term responses (tissue abnormalities), intermediate responses (growth of cultured fish), and in returning adult pink salmon from previous exposures (brood year 1998).

This project is designed to examine the natal habitat of pink salmon in PWS for evidence of exposure to polynuclear aromatic hydrocarbons (PAHs) derived from *Exxon Valdez* oil. It may be difficult to directly measure biologically available PAHs in the natal habitats 10 years after the spill, but given the levels of oil found in 1995 and the recent findings by ADF&G of elevated egg mortalities in oiled streams, we consider it very possible with the proposed detection technology. We will measure PAH in stream bank sediments (detection is highly probable), in stream sediments (not probable), in eggs (possible), and in oil collection devices (SPMD's) buried in the streams sediments (probable). Further, we will look for biological evidence of oil exposure by measuring cytochrome P4501A in emergent alevins from the streams. These measurements will be the first complete set of observations of this kind made in the oil-contaminated streams. The measurement of oil in the stream banks [repeating the Murphy et al. (in press) study] will permit the extension of the habitat contamination recovery model by 4 years. Demonstration of detectable amounts of PAHs in these environments (or their absence) will provide a direct basis for relating earlier field studies to recent laboratory studies aimed at cataloging the effects of incubating in oiled stream environments. In addition, examination of the incubating environments for evidence of contamination will provide the Trustees with a rational basis for evaluating the recovery status of pink salmon at the stream level, rather than be dependent on population levels that include hatchery production and many streams with little or no oil-exposure history.

Biomarkers like P4501A have been used before as biological evidence of oil exposure (e.g., Wiedmer et al. 1996), but the biological significance of induction is seldom known. We propose to measure cytochrome P4501A activity in emergent fry from oil-contaminated streams and compare to measurements of fry with known exposures and known biological consequences. By using fish from graded exposures and following them through the delayed impacts on marine growth, we can ascribe a biological significance (consequence) to the P4501A measurements. Further, by sampling emergent fish from project 99426 in spring 1999, we can correlate marine survival and reproductive fitness to the three exposure doses that will be released to the field (returning as adults in fall 2000). In past laboratory studies, aqueous PAH concentrations as low as 4 ppb induced cytochrome P4501A activity (Marty et al. 1997), and embryo mortality was elevated at 1 ppb (Heintz et al. 1999). However, none of these experiments were designed to identify a lowest effective concentration (LOEC) for P4501A induction, and these studies did not establish the biological meaning of exposure by relating induction to demonstrable effects. We will relate differing levels of P4501A activity to long-term effects on salmon growth because growth is a relatively inexpensive criterion to measure, and it effectively integrates most of the long-term effects that are likely to be experienced by those fish that survive the exposure period.

Lastly, the definition of pink salmon recovery, relative to habitat contamination and biological consequences will be examined. The project here will synthesize the present study results, along with other concurent and past studies to give a definitive status of pink salmon recovery.

To prevent losing an entire year of study, NMFS will up-front fund the activities required in Aug/Sept of FY 99 to collect eggs and field samples to initiate this project. These activities are needed to fit the biology of the pink salmon.

NEED FOR THE PROJECT

A. Statement of the Problem

The definition of pink salmon recovery in PWS, currently based on broad geographic populations that include fish from hatcheries and streams with little or no oil-exposure history, is not compatible with measurements of persistent oil effects in wild salmon streams. This study will provide field and laboratory evidence of pink salmon exposure in natal streams, where oil impacts have been measured as late as 1997. Interpretation of results will help to determine if wild pink salmon in PWS continue to be contaminated by EVO, or if they have recovered.

This project examines two questions: are the natal habitats of pink salmon still being contaminated by PAHs derived from the *Exxon Valdez*, and can biomarkers index injury as well as identify exposure. The first question derives from three important observations. First, pink salmon mortalities have been shown to increase at aqueous TPAH concentrations as low as 1.0 ppb (Heintz et al. 1999). Second, oiled gravel is still recoverable near several pink salmon streams in the affected sections of PWS, and third, elevated embryo mortality in oil-contaminated streams was identified as late as 1997. These observations suggest that oil from the *Exxon Valdez* may still be injuring pink salmon in contaminated streams. Consequently, pink salmon are only classified as a recovering species, despite apparently healthy escapement levels in the southwestern district. This project seeks to examine the potential for ongoing injury by quantifying the exposure experienced by pink salmon in their natal streams and identifying what sort of injury can be expected from the observed exposure levels.
This project examines the question of continuing exposure in pink salmon streams in three ways. First we propose to measure the availability of PAHs to incubating pink salmon by measuring the levels of contamination in the streambanks, and in interstitial waters. Second, the uptake of PAHs in pink salmon will be evaluated by measuring PAH levels in eyed eggs collected from oiled streams. Finally, fry from oil contaminated streams will be examined for evidence of PAH

exposure by measuring cytochrome P4501A activity in their tissues and the biological significance of these exposures will quantified with laboratory studies.

B. Rationale/Link to Restoration

Pink salmon are listed as a recovering species, and before they can be added to the list of recovered species evidence for continued exposure to oil from the *Exxon Valdez* must be considered. The original criterion the Trustees proposed to use for listing the recovery of pink salmon was the absence of demonstrable effects for two complete reproductive cycles. In 1994 through 1996, pink salmon embryos in oiled and unoiled streams had similar mortality rates, suggesting they had recovered. However, since the criterion was established it has become clear that oil can still be found near natal habitats, and that pink salmon embryos are significantly more sensitive to PAHs than previously believed. These factors may explain the elevated embryo mortalities in oiled streams observed in 1997. Thus, the original criterion for recovery should be reconsidered. We propose to ascertain the recovery status by determining if exposures are still taking place and by relating observed exposures to those known to cause injury.

Direct measurement of PAH concentrations in the natal pink salmon environments will demonstrate the plausibility of an exposure mechanism proposed by Heintz et al. (1999), and measurements in pink salmon tissues will demonstrate exposure. The hypothesized exposure mechanism suggests that PAHs leach from oil reservoirs buried in beaches alongside and above the stream channels into salmon redds via interstitial water flow. This mechanism has not been verified in the field and PAH concentrations in pink salmon tissues have not been monitored. Observation of PAH levels in streambank gravels, in interstitial waters, and in pink salmon tissues will provide a demonstration of this mechanism.

The activity of cytochrome P4501A in pre-emergent fry is an alternative method for demonstrating exposure to PAH. Cytochrome P4501A is an important enzyme system used by fish to metabolize PAHs. Elevated cytochrome P4501A activity was identified in fish taken from oiled streams as late as 1991 (Weidmer 1996) indicating exposure occurred despite the absence of detectable PAHs in the streambed gravel (Brannon et al. 1995). Although activity of P4501A was verification that salmon embryos were exposed, the relationship between P4501A induction and injury has not been evaluated. Thus, we propose to examine the relationships between P4501A induction, TPAH exposure concentration, and biological response of salmon embryos under laboratory conditions.

C. Location

Field samples will be collected from the spill zone in PWS and near Cordova. The laboratory phase of this project will take place at Little Port Walter (LPW), a research hatchery operated by NMFS in southeastern Alaska. This laboratory has been the site of many of the Trustee laboratory studies on oil toxicity to pink salmon. The facility at LPW provides easy access to the intertidally spawning pink salmon stock that has been the subject of previous experiments. In addition, the exposure apparatus requires a simulated intertidal environment and such a system is in operation at LPW.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Field collections will depend on chartering vessel and air support. Contaminated pink salmon streams have been identified by local residents. We will continue to provide information to interested public (primarily fishermen) who visit our laboratory.

PROJECT DESIGN

A. Objectives

This project has three main themes, each with specific objectives:

1. Examination of persistent *Exxon Valdez* oil in natal habitats of pink salmon in PWS, and evaluation of current contamination of eggs and alevins.

    1. *Determine how rapidly the incubating environments are recovering*
        1. Measure oil in banks adjacent to bench-mark streams last sampled in 1995 by fast-screening procedures to extend the recovery model past 1995.
    2. *Measure the availability of PAHs in the incubating environment*
        1. Measure oil in stream sediment by gas chromatography and mass spectrometry (GC/MS) to verify there is little or no contaminant directly in the stream.
        2. Measure aqueous oil contamination in salmon redds with buried semipermeable membrane devices (SPMD's) to verify oil transport interstitially to salmon redds.
        3. Verify method sensitivities by measuring oil in a stream with a known natural oil seep.
    3. *Measure exposure of eggs and fry to PAH*
        1. Directly measure oil concentrations in eggs by GC/MS, and compare to concentrations in SPMD's.
        2. Inspect eggs for indirect evidence of exposure to oil using the biomarker cytochrome P4501A as an index of exposure and compare to PAH concentrations in eggs and SPMD's.

2. Examination of the usefulness of the biomarker cytochrome P4501A as a predictor of the biological impacts of oil exposure
    1. *Controlled laboratory test with graded oil doses to establish a dose-response curve at part per billion levels.*

B. *Influence of exposure level on the prevalence of cytochrome P4501A activity and embryo tissue*
   1. Inspect emergent fry for gross and histological lesions.
   2. Determine P4501A induction in organ tissues.

C. *Initiation of cytochrome P4501A activity in developing pink salmon*
   1. At one dose, measure P4501A response at four developmental stages to determine the onset of induction.

D. *Relation between cytochrome P4501A activity and short and long-term effects*
   1. Relate P4501A induction to growth of experimental fish cultured at LPW (brood year 99) from the graded series of oil exposures.
   2. Relate P4501A induction to ocean survival (brood year 98) and reproductive fitness of returning adults to parts per billion exposures from the companion pink salmon toxicity study 99476.

3. Synthesis of this project, and long-term impact data from other projects, to redefine pink salmon recovery in PWS, and provide a status of that recovery.

The first theme provides a basis for testing the hypothesis that pink salmon, incubating in previously oiled streams, continue to be exposed to PAHs derived from the *Exxon Valdez*. Testing this hypothesis entails three major tasks: 1) determine how rapidly oil reservoirs are being depleted by sampling gravel from the deltas of streams identified as benchmarks in 1989 and resampled again in 1995 (Murphy et al. In press); 2) measure the availability of PAHs in the incubating environment by sampling the water flowing through salmon redds for PAHs using semi-permeable membrane devices (SPMDs), and characterizing the PAH levels in gravels alongside, above, and in the stream channels; 3) establish the availability of PAHs to the eggs by measuring PAH concentrations in eyed eggs and activity of cytochrome P4501A in emerging fry. This latter task will be limited to those sites identified with highest risk as determined by fast screening methods. Each of these tasks will be performed in oiled and unoiled streams selected on the basis of their contamination histories. In addition, the sensitivity of these approaches will be examined by duplicating these approaches in a stream outside PWS, but known to contain a natural oil seep. The seep stream will be an "oiled control."

The second theme tests the hypothesis that increasing PAH levels increase the prevalence of cytochrome P4501A activity and result in long-term injury. P4501A has long been known to document exposure, but the biological consequences are unknown. This hypothesis requires a laboratory study designed to determine 1) when cytochrome P4501A activity becomes detectable in developing embryos, 2) how exposure level influences the prevalence of cytochrome P4501A activity in specific tissues, and 3) the relationship of P4501A activity to both short- and long-term biological response. We propose to incubate pink salmon eggs in variety of TPAH concentrations and examine them periodically for evidence of cytochrome P4501A activity. Prevalence is defined as the product of the intensity of staining and occurrence in histologic sections of tissue examined for P4501A activity by immunochemical staining. The first task is required, because the time of onset may be a better predictor of long-term effects than prevalence at emergence. Induction prevalence will be related to the dosing histories to develop a dose-response curve. The relationship between long-term effects and prevalence will be examined by holding fish from the same exposure groups in captivity and examining them for dose related differences in growth rate.

Synthesis of the first two research themes will provide a rational basis for judging whether or not wild pink salmon stocks in PWS have recovered from the *Exxon Valdez* oil spill. The study will determine if pink salmon eggs are currently being exposed to hydrocarbons in oil-contaminated streams, and how quickly these sensitive environments are recovering. In addition, the development of a relationship between cytochrome P4501A activity and long-term effects will provide a basis for further evaluating the severity of the exposures indicated by P4501A activity in salmon embryos in first two years after the spill.

B. Methods

Theme 1. Examination of persistent *Exxon Valdez* oil in natal habitats of pink salmon in PWS, and evaluation of current contamination of eggs and alevins.

Determine how rapidly the incubating environments are recovering

Gravel samples from each of the 9 oiled index sites identified in Murphy et al. (In press) will be collected using the procedures described in that report. In addition, oil reservoirs identified in 1995 will also be sampled to determine how rapidly they are weathering. All samples will be collected from sites sampled in 1989 and 1995. All the gravel samples will be analyzed by ultraviolet fluorescence, a fast screening procedure that can be used to identify samples with sufficient amounts of oil to warrant more detailed analysis by GC/MS. The fast screening results as well as the more detailed analyses can be compared to similar data collected in 1995. These data will be combined with those reported by Murphy et al (In press) to extend their recovery model.

Measure the availability of PAHs in the incubating environment

Exposure levels in streams contaminated by the *Exxon Valdez* oil spill will be monitored in the 9 streams identified as having the highest embryo mortality rates in 1997, the 3 reference streams with the lowest mortality rates, and 1 stream with a naturally occurring oil seep (Bue et al. 1998). The Katalla slough, located east of the Copper River, has a natural oil seep and is a cataloged anadromous stream bearing pink salmon. The existence of oil in Katalla slough will provide a measure of the sensitivity of our analyses for detecting petrogenic PAHs in interstitial waters and pink salmon tissues.

Sampling protocols applied to each stream will follow the general procedure of Bue et al. (1996). Streams will be divided into four sections based on their position above mean lower low water and sampling transects will be established in each section using maps developed by Bue et al. (1998). Transect locations will coincide with those used in 1997 whenever possible. Personnel

with ongoing experience conducting egg-dig transects in PWS will be contract (i.e., the same crew that ADF&G uses).
Sampling will begin prior to the arrival of adult pink salmon in 1999. Gravel samples will be collected from the stream banks 1 m upstream from either end of each transect as well as from the streambed in the center of each transect. In addition, conspicuous oil deposits located above the stream channel will also be sampled opportunistically. Dissolved PAHs will be sampled by burying a pair SPMDs in pits dug into the streambed near the end of each transect and in the middle. One member of each pair will be recovered approximately 45 days later (during egg digs), and the second the approximately 175 days later during the following spring during emergent fry sampling. The depths of SPMD burial will be similar to the depths of redds constructed by pink salmon.

PAH levels in gravel samples and SPMDs will be determined by gas chromatography and mass spectrometry (GC/MS) using the methods described by Short et al. (1996). Prior to analysis, sediment samples will be fast-screened to determine the concentrations of total petroleum hydrocarbons (PHCs) by ultraviolet fluorescence. Samples with detectable levels of PHCs will be further analyzed by GC/MS. All the SPMDs from transects found to be downstream from gravel samples with detectable PHCs will also be sampled by GC/MS to determine PAH levels. PAH levels in stream bank sediments and streambed gravels will be used to map the distribution of oil in the incubating habitat, while PAH observations collected from SPMDs will be used to examine the transport of PAHs to incubating habitats.

Measure exposure of eggs and fry to PAH

Availability of PAH's to eggs and fry will be measured in two ways, by PAH concentration in egg tissue, and induction of cytochrome P4501A. Uptake of PAH will be measured in eyed eggs and pre-emergent fry sampled along the transects established to deploy the SPMDs. In early October 1999, each transect will be visited to obtain samples of eyed eggs, and establish the density and mortality of developing eggs in the study streams. The procedure will be repeated in March 2000 to obtain a set of pre-emergent fry for analysis of cytochrome P4501A activity. Eyed eggs and pre-emergent fry will be obtained by hydraulic sampling along the established transects using methods described by Pirtle and McCurdy (1977). Preferred samples of eyed eggs and pre-emergent fry will come from locations nearest each of the SPMDs. The eyed eggs will be frozen immediately after collection to be examined for PAHs by GC/MS. Pre-emergent fry will be preserved in formalin in individual cassettes for later processing to determine cytochrome P4501A induction using immunohistochemical staining. Samples will be analyzed blind.

The only samples of eyed eggs and pre-emergent fry to be processed will be those with the greatest likelihood of having detectable PAHs or P4501A induction. Sample sets will be selected on the basis of the analytical results of oil deposits in associated streambank gravel and SPMD samples. Levels of PAH observed in eyed eggs will be used to demonstrate exposure levels and these will be compared with those observed in laboratory studies described by Heintz et al. (1999). The overall distribution of PAHs in the natal habitats as determined by the environmental data will be compared to estimates of embryo mortality along each transect.

Theme 2. Examination of the usefulness of the biomarker cytochrome P4501A as a predictor of the biological impacts of oil exposure

Controlled laboratory test with graded oil doses

Developing pink salmon eggs will be exposed to oil contaminated water using the laboratory methods described in Marty et al. (1997). Approximately 10,000 eggs will be exposed to each of 5 doses, in order to provide sufficient numbers of fry for examining long-term affects on growth. Procedures used to determine embryo mortality rates and quantify exposure levels will follow previously described methods (Marty et al. 1997).

Influence of exposure level on the prevalence of cytochrome P4501A activity and organ tissue

Emerging fry will be counted, inspected for gross lesions and sampled to examine the presence of cytochrome P4501A activity. Aliquots of 12 fry from each dose will be retained for analysis of cytochrome P4501A induction with immunohistochemical staining. Fry will be retained in individual cassettes in buffered formalin and shipped to UC Davis for processing. Histological sectioning and determination of cytochrome P4501A induction will follow the procedures described in Marty et al. (1997). Sections of preserved fry will be cut to ensure staining of at least the gill, pharynix, kidney, intestine, heart, liver epidermis and yolk sac. Scores for staining intensity and occurrence will be compared by regression to exposure history to determine which tissue or combinations of tissues are the best indicators of exposure level.

Initiation of cytochrome P4501A activity in developing pink salmon

Alevins from the highest exposure level will be sampled monthly to determine when cytochrome P4501A activity is initiated during development.

Relation between cytochrome P4501A activity and long-term effects

Two methods will be used to relate induction of P4501A to long-term biological effects, including marine survival (1998 brood year) and growth of cultured fish (1999 brood year). Marine survival and reproductive fitness of returning adults will be determined for fish in a previous experiment (study number 99476), where the number of oil exposures was limited to two, but P4501A induction will be determined in eyed eggs and emergent fry sampled prior to release (spring 1999).

Experimental fry from the 1999 brood year will be cultured in net pens for 5 months to determine the value of P4501A activity for predicting long-term effects of embryonic exposure to PAHs on marine growth. Fry will be transferred to separate containers depending on their exposure histories and cultured until they are large enough to tag with passive integrated transponder (PIT) tags. Fry transferred to the culture containers will be measured to determine each group's average weight and length. At tagging the length and weight of each individual will be recorded and growth will be calculated as the difference in the logs of the weight at tagging and the group's initial mean weight divided by the number of elapsed days. After tagging, individual growth records for each fish will be developed by periodically sampling the tagged population. Mean growth rates for each exposure group will be compared to their exposure history and the average combined score for intensity and occurrence for cytochrome P4501A activity in the given exposure group at emergence.

C. Cooperating Agencies, Contracts and Other Agency Assistance

Sampler deployment, initial sample collections, hydrocarbon analysis, laboratory exposures and methods development will be provided by NMFS. Sample collection, in PWS will be performed with a contract with a local vessel using methods developed by ADF&G. Analysis of cytochrome P4501A will be provided by contract with UC Davis.

SCHEDULE

0. Measurable Tasks donated in FY 99

April 1999: Collect emergent fry for P4501A analysis from exposed fish (brood year 98)
August. 1999: Deploy samplers in stream beds, collect gravel samples, set-up laboratory experiment.

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

Fall 1999:	Field:	collect SPMDs and eyed eggs from streams
	Lab:	collect eyed eggs to determine onset of P4501A activity.
Winter 99/00	Field:	Begin fast-screen analysis of gravels, and GC/MS analysis on SPMDs and eggs.
	Lab:	Collect alevins for P4501A induction
Spring 2000:	Field:	Collect fry samples for P4501A and remaining SPMDs from streams.
	Lab:	Collect final P4501A samples. Evaluate fry surviving exposures. Begin analysis of fry for cytochrome P4501A activity, and growing out fry exposed in laboratory.
Summer 2000	Lab:	Tag cultured fry.

[FY01 begins about here]

Fall 2000: Complete GC/MS analysis of remaining samples, and complete analyses of growth.

Winter 2001: Complete data analysis. Begin writing manuscripts.

B. Project Milestones

Summer 1999 Initiate field and laboratory studies

Spring 2000: Complete field study. Continue to grow laboratory fry.

Fall 2000: Complete hydrocarbon analyses

Jan. 2001: Complete laboratory data collection (P4501A activity), complete data analysis, and begin writing manuscripts

Summer 01: Submit manuscripts to journals

Oct 2001 Submit final report.

C Completion Date

Final Report will be submitted on Oct 1, 2001.

PUBLICATIONS AND REPORTS

Final Report

Peer-reviewed manuscripts:

Murphy, M.L. et al. 2001. Hydrocarbon contamination and recovery of pink salmon spawning areas a decade after the *Exxon Valdez* oil spill. Journal unknown.

Carls, M.G. et al. 2001. Persistent exposure of pink salmon to *Exxon Valdez* oil a decade after the spill. Journal unknown.

Marty, G.D. et al. 2001. Developmental appearance of P4501A biomarker in pink salmon eggs and larvae. Journal unknown.

Heintz, R. et al. 2000. Feasibility of using biomarkers to regulate water quality. Journal Unknown.

Heintz, R. et al. 2001. Relation of P4501A biomarker in alevin pink salmon to long-term grow and reproductive fitness. Journal unknown.

Rice, S.D. et al. 2001. Long-term biological and ecosystem recovery for pink salmon after the *Exxon Valdez* oil spill. Journal unknown..

PROFESSIONAL CONFERENCES

No conferences planned in FY 00, travel to 2000 Oil Spill Symposium is included. (Travel to conferences is planned for FY01.)

NORMAL AGENCY MANAGEMENT

This project seeks to determine the recovery status of pink salmon through a cooperative relationship between NMFS and the Trustees. There is no charge for project support costs which include management of the LPW facility and project budget.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The design of this project has been coordinated with the work performed in the past by ADF&G under Restoration 191A, and the work performed by NMFS under 191B and 194. Investigators and agencies will coordinate by sharing data. NOAA/NMFS will coordinate with the Trustees by providing labor requirements and laboratory overhead. This project also coordinates with pink salmon reproductive fitness project 99426 by collecting emergent fry for P4501A analysis (brood year 98).

PROPOSED PRINCIPAL C0-INVESTIGATOR

Name	Dr. Stan Rice
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E-mail	jeep.rice@noaa.gov

PRINCIPAL Co-INVESTIGATOR

GS-13 Physiologist - Stanley D. Rice

Received BA (1966) and MA (1968) in Biology from Chico State University, and PhD (1971) in Comparative Physiology from Kent State University. Employed at Auke Bay Fisheries Laboratory since 1971 as a research physiologist, task leader and Habitat Program Manager since

1986. Rice has researched oil effects problems since 1971, and has published over 100 papers, including over 75 on oil effects. Studies have ranged from field to lab tests, behavioral to physiological to biochemical studies, from salmonids to invertebrates to larvae to meiofauna. Rice has conducted and managed soft funded projects since 1974, including the Auke Bay Laboratory *Exxon Valdez* damage assessment studies since 1989. Activities since the oil spill have included leadership and management of up to 10 damage assessment projects, field work in PWS, direct research effort in some studies, establishment of state of the art chemistry labs and analyses in response to the spill, quality assurance procedures in biological-chemical-statistical analyses, establishment of hydrocarbon database management, servicing principal investigators and program managers in NOAA and other agencies with reviews and interpretations, direct input into agency decisions, interaction with other agencies in various ways (logistics coordination, critique experimental designs, interpret observations, etc.), and lead editor of the first Trustee symposium proceedings.

PRINCIPAL Co-INVESTIGATOR

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PRINCIPAL Co-INVESTIGATOR

Mark G. Carls (GS-12 Fishery Biologist)

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

OTHER KEY PERSONNEL

Appendix:
Sample design

1. Examination of persistent *Exxon Valdez* oil in natal habitats of pink salmon in PWS, and evaluation of current contamination of eggs and alevins.

1. *Determine how rapidly the incubating environments are recovering*
    1. Measure oil in banks adjacent to bench-mark streams last sampled in 1995 by fast-screening procedures.

        oiled: 9 oiled streams * 4 transects/stream * 2 samples/transect = 72
        + 4 mapped locations/ stream * 7 oiled streams = 28
        total oiled = 100 UVF samples
        reference: 3 reference streams * 4 transects/stream * 2 samples/transect = 24
        Combined total = 124 UVF samples.
        All UVF samples will be collected on a single trip - i.e., the effort will not be duplicated later. (The 2 samples from each transect will consist of bank sediments at each end of the transect.

2. *Measure the availability of PAHs in the incubating environment*
    1. Measure oil in stream beds by gas chromatography and mass spectrometry (GC/MS).

        oiled: 9 oiled streams * 4 transects/stream * 1 sample/transect = 36
        reference: 3 reference streams * 4 transects/stream * 1 sample/transect = 12
        Combined total = 48 GC/MS samples. Assume a maximum of 40 samples will require processing. These GC/MS samples will be collected from the central stream channel - i.e., roughly in the center of each transect. (Purpose - demonstrate lack of PAH in gravel despite presence in aqueous form and in eggs.)

    2. Measure aqueous oil contamination in salmon redds with buried semipermeable membrane devices (SPMD's).

        oiled: 9 oiled streams * 4 transects/stream * 2 SPMD/transect = 72
        reference: 3 reference streams * 4 transects/stream * 2 SPMD/transect = 24
        Combined total = 96 SPMD samples.
        SPMD's will be located in pairs in stream channels. The first of each pair will be retrieved after 45 d, the second after about 175 d.

    3. Verify method sensitivities by measuring oil in a stream with a known natural oil seep.

        Gravel: 1 stream * 4 transects/stream * 3 samples/transect = 12 UVF samples
        Gravel: 1 stream * 3 verification samples/stream = 3 GC/MS samples

Water: 1 stream * 4 transects/stream * 1 SPMD/transect = 4 SPMD samples

3. *Measure exposure of eggs and fry to PAH*
   1. Directly measure oil concentrations in eggs by GC/MS.

      oiled: 9 oiled streams * 4 transects/stream * 1 sample/transect = 36
      reference: 3 unoiled streams * 4 transects/stream * 1 sample/transect = 12
      Combined total = 48 GC/MS samples. Assume that no more than 28 samples will require analysis, based on SPMD analysis.

   2. Inspect eggs for indirect evidence of exposure to oil using the biomarker cytochrome P4501A as an index of exposure.

      oiled: 9 oiled streams * 4 transects/stream * 6 fry/transect
      reference: 3 unoiled streams * 4 transects/stream * 6 fry/transect
      Combined total = 360 histo samples collected. Assume a maximum of 124 samples will require processing, based on SPMD and GC/MS analysis. The number of possible analyses could be increased or decreased depending on requirements of the seep stream and the laboratory study.

C' Measure exposure of eggs and fry to PAH in seep stream
   1. Directly measure oil concentrations in eggs by GC/MS.

      1 stream * 4 transects/stream * 1 sample/transect = 4 GC/MS samples. Assume all 4 samples will require GC/MS analysis, based on SPMD results

   2. Inspect eggs for indirect evidence of exposure to oil using the biomarker cytochrome P4501A as an index of exposure.

      1 stream * 4 transects/stream * 6 fry/transect = 24 histology samples.

2. Examination of the usefulness of the biomarker cytochrome P4501A as a predictor of the biological impacts of oil exposure

A. *Controlled laboratory test with graded oil doses: samples required for experimental monitoring and parallelism with field component*

   1. Measure oil in dosing apparatus and in treatment water

      Gravel samples from dosing apparatus: 5 doses * 3 replicates/dose * 2 sample times (beginning & end of dose) = 30 GC/MS samples.

      Treatment water: 5 doses * 3 replicates/dose * 3 sample times (beginning, eyeing, & emergence) = 45 GC/MS samples

No SPMD samples.

2. Measure oil in eggs at eyeing

   5 doses * 3 replicates/dose * 2 observations/replicate, where observations are at eyeing and emergence, + 4 (monthly) samples * 3 replicates at the highest dose = 42 GC/MS samples

B. *Influence of exposure level on the prevalence of cytochrome P4501A activity and embryo tissue*

1. Inspect emergent fry for gross and histological lesions.

   dose series: 5 doses * 6 fry/dose * 2 life stage (eyeing, emergence) = 60
   Combined total = 60 histology samples.

2. Determine P4501A induction in organ tissues.

   The previously collected samples collected (step 1 immediately above) will also be processed for P4501A induction.

C. *Initiation of cytochrome P4501A activity in developing pink salmon*

1. At one dose, measure P4501A response at four developmental stages to determine the onset of induction.

   Time series at 1 dose: 1 dose * 6 fry/dose * 4 life stages (including eyeing, ... emergence) = 24 induction samples, also to be processed for gross & histological lesions.

4. *Relation between cytochrome P4501A activity and short and long-term effects*

1. Relate P4501A induction to growth of experimental fish cultured at LPW (brood year 99).

   No chemical sampling required.

2. Relate P4501A induction to ocean survival (brood year 98).

   Activities are handled in project 99476.

Amendment 1: Hydrological- survey, Project 00454

The purposes of the hydrological survey is to provide corroborating evidence of water exchange between sediment in stream banks, stream water, and salmon redds. This study will be a dye study, and will compliment the other efforts to measure hydrocarbons in salmon redds using SPMD's and P450 analyses in alevins. The methods will involve depositing non-toxic dye into stream banks, and measuring pore water samples from different sites in the delta, including salmon redds in the stream channels. This will be done repeatedly through tidal cycles, with water measurements on site using a field fluorometer. Several hundred water measurements are anticipated over the course of a week. The methods will be worked out at a logistical site near Juneau or Little Port Walter before being transported into two oiled streams in PWS.

Two accomplish this objective, other secondary objectives will also have to take place: 1) map the physical characteristics (tidal heights) of each stream surveyed, 2) search for evidence *Exxon Valdez* oil remaining in stream sediment, 3) and characterize the sediment structure.

Map physical characteristics and collect sediment

To augment the hydrocarbon data collected for the purpose of documenting the current possibility of pink salmon egg exposure during incubation in previously oiled streams in PWS, a minimum of 2 oiled streams in PWS will be surveyed. Methods will be tested and refined in a Southeast Alaska stream before beginning hydrological surveys in PWS. Surveys will be conducted after fry emigrate from streams in 2000 to avoid possibly staining emergent fry. Survey data will include mapping, elevation profiles, gravel samples for grain and hydrocarbon analysis, and hydrodynamics. Mapping and elevation measurements will be accomplished with a laser level. Fixed transects across each stream will be located within each of the 4 tide zones routinely sampled by Bue et al. (1.8-2.4, 2.4-3.0, 3.0-3.7, and >3.7 m above mean lower low water), parallel to each other, and roughly perpendicular to the stream flow (see figure). Elevation profiles will be developed for each transect. Water and sediment samples will be collected at intervals along each transect (see Figure). Sediment samples will be collected, stored, and analyzed according to standard ABL operating procedures. Additional sediment samples will be dry-sorted using sieves based on the Wentworth scale to calculate fredle indices.

Provide evidence of water exchange between sediment in stream banks and streams

To determine the potential for oil movement from stream banks into salmon redds, fluorescent dyes will be placed in sediment, and downstream water will be collected at redd depth. Collectors will consist of vertical tubes placed in stream substrate along the previously described transects. Holes near the bottom of each tube will allow collection of water at depth after partial tube submergence. Dye will be injected into upstream tubes or banks at low tide, and water in each fixed downstream tube will be periodically monitored through the next tidal cycle. Additional samples will be collected at the water surface near each tube for comparison, and any visual evidence of the dye will be recorded. Samples will be inspected for visual evidence of dye, and further processed with a fluorometer. Each sample will simply be scored for the presence or absence of the dye, location, and time of observation. If dye is not detected in any samples, the experiment will be repeated with dye injected closer to the stream banks. Repeated observations will be limited to 3 tide cycles. Water velocity, direction, and depth will be periodically recorded adjacent to each collection pipe.

Dye injection will be varied depending on initial results. Preliminary methods will include dye injection directly upstream to demonstrate that dye is detectable downstream. The next approach will be to simultaneously locate dye capsules in several places on upstream banks. Detection of dye in downstream locations will demonstrate water exchange between banks and stream, but will not pinpoint sources. Assuming these methods work, further refinements are possible, including the positioning of a single dye source at various distances from stream banks and release of dye from previously oiled areas. In PWS, the first method tested at a given stream will likely be to release dye in previously oiled banks. If dye is subsequently detected in the stream, no further injections will be necessary.

Survey schedule

We anticipate that a schedule will go something like this.

day	activities
1	map, including collection of elevation data collect sediment samples for hydrocarbon & grain analysis determine transect positions place water sampler tubes
2	Inject dye: monitor water through 1 tidal cycle. Collect periodic water samples, analyze.
2	Half the crew will repeat the day 1 process at a second near by stream. This stream will be sampled by some of the crew on a staggered sampling basis, while one analyst will remain on the charter vessel analyzing samples as they are returned from the two streams. 3 if required, repeat day 2, but change injection locations
3.	if required, repeat day 2, but change injection locations

It is possible that the goals of the field study could be accomplished in 4 working and two travel days. We are optimistic that we will achieve the results we want, but not that optimistic that it can be done in 4 working days. Hence we figure 8 working days. Each stream will be different-different in topography, flow, etc. We assume that there will have to be adjustments to each stream, and that it will take a few days for each stream, even if we are lucky enough to stagger them in sampling. Further, we do not believe we can accomplish the goal by bringing samples back. We need feedback from the field, to make adjustments in dye location. There is some cross over with the sampling of oil and alevins, in information, but NOT in logistics. We have to conduct some of the sampling when eggs and alevins are present; and we have to conduct this study when NO ALEVINS are present, otherwise we would potentially stain fry, marking them with fluorescence and certain predation. The risk to excessive predation to a stream does not permit a logistics overlap.

Specific budget for Hydrological study- termed dye study in the project budget

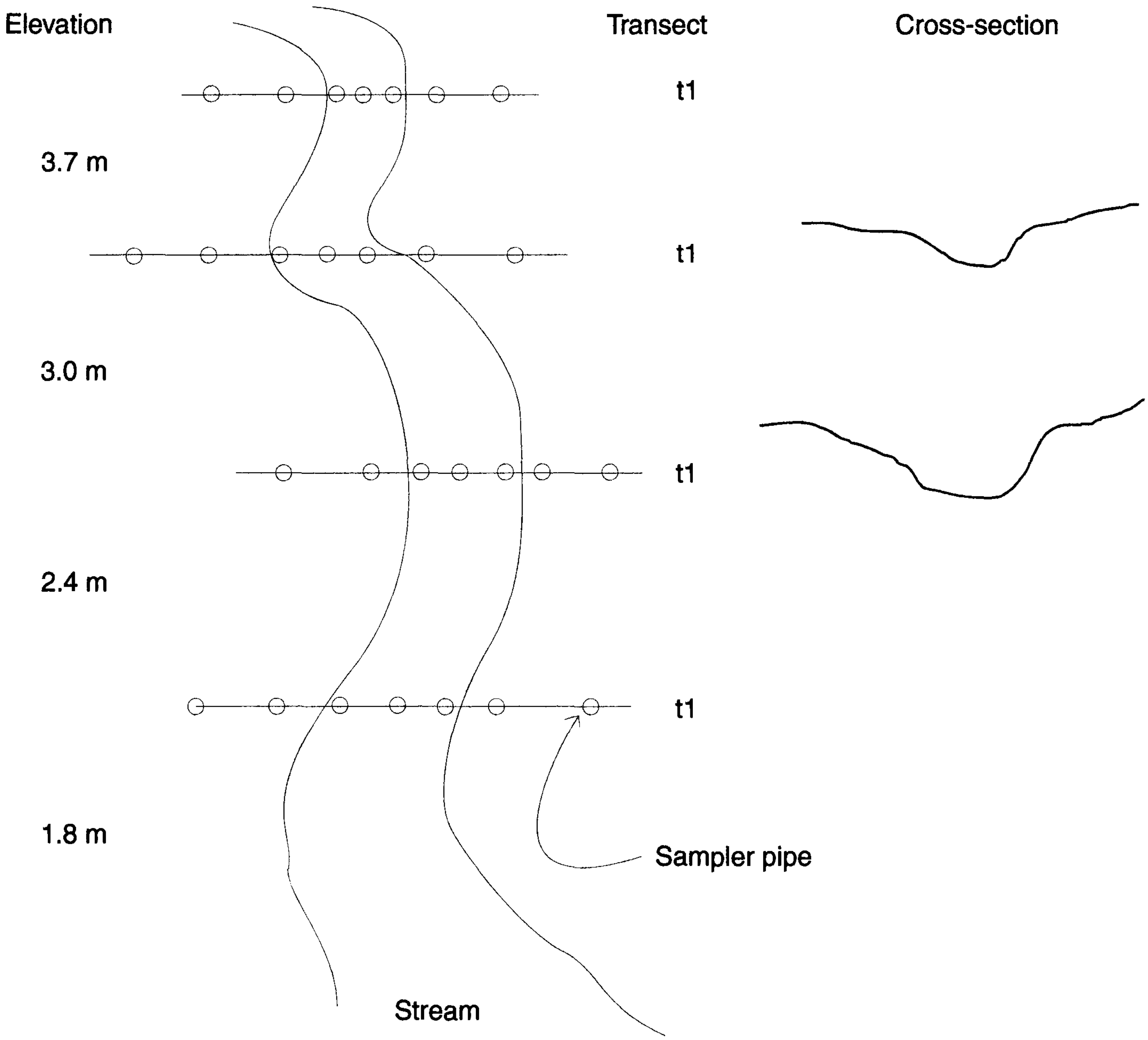
Boat Charter:
Assume 2 streams * 4 d/stream = 8 d
8 d * 1500 $/day = $12,000.

water meter	800	
pipe & caps	1400	1" dia galv * 6' pipe * 30 pipes/site
field fluorometer	5000	
fluorescent dye	1824	estimate 4/stream/day * 4 days *4 streams * $28.50
misc. supplies	2000	
sample bottles, cuvettes, misc field gear		
trips to Cordova	1480	4 people * 370 $/ticket
total rough cost	$24.8 k	

borrow (or lease): Do not buy.

laser level	1,300
tripod	150
stadia rod	100

Hydrology



Elevation
Transect
Cross-section
t1
3.7 m
t1
3.0 m
t1
2.4 m
t1
1.8 m
Sampler pipe
Stream

7-2-c revision
approved TC 8-9-99

FY 00 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$128.8						
Travel		$63.6						
Contractual		$96.3						
Commodities		$19.3						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$308.0		Estimated FY 2001	Estimated FY 2002	Estimated FY 2003		
General Administration		$26.1						
Project Total	$0.0	$334.1		$104.0				
Full-time Equivalents (FTE)		1.9						
	Dollar amounts are shown in thousands of dollars.							
Other Resources		$48.0						

Comments:
NOAA Contributions:

Habitat Program Manager and Co-PI, Stan Rice 1.0 mo @ 12.2K, Senior Chemist Jeff Short 1 mo @ 9.4K, Ron Heintz 1.5 mo @ 11.1K, Mike Murphy 2 mo @ 15.2K for a total NOAA contribution of 48K.

Laboratory facilities at LPW and ABL.

FY 00

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: National Oceanic and Atmospheric Administration

FORM 3A
TRUSTEE
AGENCY
SUMMARY

FY 00 EXXON VALDEZ TRUSTEE 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
Mike Murphy	Fishery Research Biologist	12/5	1.0	7.6		7.6
Mark Carls	Fishery Research Biologist	12/6	1.0	7.8		7.8
Robert Bradshaw	Fishery Research Biologist	11/2	6.5	6.1		39.7
Mandy Lindeberg	Fishery Research Biologist	9/2	5.8	4.7		27.3
Larry Holland	Chemist	11/5	1.0	6.7		6.7
Marie Larsen	Chemist	11/5	1.0	6.7		6.7
Josie Lunasin	Chemist	9/6	6.0	5.5		33.0
Dr. Stan Rice	Program Manager	14	0.0	12.2		0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		22.3	57.3	0.0	
					Personnel Total	$128.8

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2000
EVOS workshop in Anchorage	0.4	2	6	0.1	1.4
					0.0
Vessel Charter PWS - SPMD survey		2	12	2.5	30.0
(12 streams/2 streams/day, 6 days per trip @ 2.5 K/day)					0.0
					0.0
Air Charters PWS- SPMD deployment					0.0
travel to Cordova (deploy, eyeing, emergence)	0.3	7	7	0.1	2.8
air charter - helo - 1K/day plus fuel for 2 round trips)	3.8	2			7.6
air charter fixed wing 1K/day	1.0	1			1.0
Air charters to LPW	0.9	8			7.2
Vessel charter costs for dye study(4 streams, 8 days 1.5K/day)					12.0
Travel to Cordova for dye study	0.4	4	8		1.6
				Travel Total	$63.6

FY 00

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Personnel
& Travel
DETAIL

FY 00 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Contractual Costs:	Proposed
Description	FY 2000
4A Linkage	50.0
LPW labor ($15/hour for 3 total people for pre-eye and emergence labor , = $120/day for 60 work days)	10.8
Chem lab sample processing at ABL	
UV screening for gravel and eggs (184 samples)	4.5
GC/MS eggs, gravel water	25.0
(these costs are approximately 1/3 of the processing cost, the remaining cost is accounted for in salary)	
SPMD processing	6.0
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$96.3

Commodities Costs:	Proposed
Description	FY 1999
SPMD deployment supplies	
anchors, tubes, hardware (40 anchors & tubes @ $52 plus cables, connectors etc)	3.0
pit tags	3.0
sample jars & supplies	2.0
Dye supplies	
fluorometer, dye, misc supplies, pipe& caps, water meter	11.3
Commodities Total	$19.3

FY 00

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Contractual &
Commodities
DETAIL

FY 00 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
			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
LPW hatchery		NOAA
Pit detectors		NOAA
ABL chemistry laboratory		NOAA

FY 00

Prepared 7/2/99 p 4/8

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Equipment
DETAIL

FY 00 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1998	Proposed FY 1999						
Personnel		$0.0						
Travel		$0.0						
Contractual		$50.0						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$50.0		Estimated FY 2000	Estimated FY 2001	Estimated FY 2002		
Indirect								
Project Total	$0.0	$50.0						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY 00

Prepared 7/2/99 p 5/8

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: Dr. Gary Marty, Fish Pathology Services, Davis, CA

FORM 4A
Non-Trustee
SUMMARY

FY 00 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Personnel Costs:							
	Name	Position Description		Months Budgeted	Monthly Costs	Overtime	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
		Subtotal		0.0	0.0	0.0	
						Personnel Total	$0.0

Travel Costs:						
	Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FY 2000
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$0.0

FY 00

Prepared 7/2/99, p 6/8

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: Dr. Gary Marty, Fish Pathology Services, Davis, CA

FORM 4B
Personnel
& Travel
DETAIL

FY 00 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 1999 - September 30, 2000

Contractual Costs:			Proposed
Description			FY 2000
Dr. Gary Marty -			
purpose: Histopathology and	n	cost/n	
P450 analyses, divided among PWS, LPW, & Katala samples	240	215.38	50.0
n refers to number of fish processed which icludes the following samples:	144		
PWS 3 oiled streams * 4 transects/stream * 12 fry/transect =	60		
Lab 5 doses * 12 fry/dose * 1 life stage (emergence) =	36		
+ time series at 1 dose; 12 fry * 3 life stages =			
			$50.0

Commodities Costs:	Proposed
Description	FY 2000
Commodities Total	$0.0

FY 00

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: Dr. Gary Marty, Fish Pathology Services, Davis, CA

FORM 4B
Contractual & Commodities
DETAIL

FY 00 EXXON VALDEZ TRUSTEE 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
				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	

FY 00

Prepared 7/2/99 p 8/8

Project Number: 00___
Project Title: Pink Salmon Recovery: Evidence & Consequences of Persistence Oil Contamination in Pink Salmon Natal Habitats
Agency: Dr. Gary Marty, Fish Pathology Services, Davis, CA

FORM 4B
Equipment
DETAIL

Revision 7-30-99
approved TC 8-9-99

An Evaluation of the Data System for the EVOS Long-Term Monitoring Program

Project Number:	00455-BAA
Restoration Category:	Monitoring
Proposer:	C. Falkenberg/Ecologic Corp.
Lead Trustee Agency:	NOAA
Cooperating Agencies:	None
Alaska SeaLife Center:	No
New or Continued:	New
Duration:	1st yr. 1 yr. project
Cost FY 00:	$89.0
Cost FY 01:	$0.0
Cost FY 02:	$0.0
Geographic Area:	All
Injured Resource/Service:	All

ABSTRACT

This project will report on the data system issues related to GEM (Gulf Ecosystem Monitoring), the Trustee Council's long-term monitoring and research program. In addition to the data collection effort, data delivery will prove to be a critical component of the success of GEM. Therefore, the data system issues need to be part of the planning process. This project will outline some of the key data and user issues and produce a report analyzing existing systems that deliver similar data. In addition, strawman proposals will be developed for a range of data systems that could meet the needs of the GEM program.

Introduction

In April of 1997 the Chief Scientist proposed a long-term monitoring and research program as part of the legacy of the Exxon Valdez Oil Spill. Although the details of the monitoring program are still evolving, it will include the collection of data from a variety of sources and the creation of a long-term data archive. The effective use of the data archive by the stakeholders will depend on the effectiveness of the data system that will manage that archive and provide access to the data. We are proposing to investigate the issues relating to that data system so that they might be included in the planning of the long-term monitoring and research program. We will also propose one or more data systems that could serve the stakeholders interested in accessing the data that will be collected as part of GEM.

The data system will need to provide access to many types of ecosystem data describing the shelf region of the northern Gulf of Alaska. The user community will likely include resource managers, earth system scientists, land use planners, local communities, educators, and other, as yet unidentified stakeholders, as well. It will contain data from the GEM program, from previous EVOS funded research, and possibly from include pertinent federal and local data that would be critical to the long term tracking of the coastal ecosystems of Prince William Sound and Lower Cook Inlet.

The successful delivery of the data collected and archived as part of the GEM program will be key to its long-term effectiveness. Therefore the single goal of building a data system is to provide a vehicle that allows the most cost-effective use of the data collected and maintained by the monitoring program. If the stakeholders cannot find or use the data, the collection effort itself will have been compromised. An effective data delivery system increases the value of the data by increasing the long-term use of those data by the widest number of stakeholders and applications.

Scientific data systems are, however, a rapidly evolving technology. With the advent of the World Wide Web (WWW) many scientific disciplines have made data available to the public and to fellow researchers. Some of these systems have enjoyed the active involvement of members of the discipline and others have been less inspired and less effective. However the problems that accompany scientific data can be as disparate as the disciplines themselves. As an example, remotely sense data can voluminous, simple, and require special viewers while manually collected data may have a complex structure with many coded values that require lookup tables.

The successful systems have been well planned with a clear set of users and services in mind. We believe, therefore, that these data system issues need to be part of the planning for the long-term monitoring program and that the first step is to examine some other data systems and see how they have succeeded or failed.

We are proposing a small pilot project to investigate the data system issues that need to be considered as the long-term monitoring and research program is brought into focus. We will present the data system issues and the ramifications of some of the choices that will be made in the planning phase of the program. We will use the most current description of GEM as a starting point to estimate the data and user requirements. We will present some of the data system issues that will accompany the data that might be collected and the users that might access them. After identifying these issues, we will research several other scientific data systems and draw conclusions about how those systems resolved the same issues. And finally, we will propose one or more data systems that can be used as strawmen in the discussion and planning for GEM.

Together, our experience spans many types of data and many existing data systems. We will use our experience with the Sound Ecosystem Assessment (SEA) project database to evaluate the challenges of managing similar datasets that were collected as part of the EVOS research program. We also have experience with several grass roots data systems in the space sciences, and with more top down NASA data systems that support the Earth Observing System (EOS). Finally we will look into some of current data systems which have GIS and ecosystem data for the northern Gulf of Alaska region including the Cook Inlet Information Management and Monitoring System (CIIMMS) and the Alaska Geographic Data Clearinghouse (AGDC).

Need for the Project

A. Statement of Problem

In his position paper from April 1997 the chief scientist calls for a "permanent, adaptive, interdisciplinary monitoring and research program" designed to carry on a subset of the research and monitoring that has been supported by the Trustee Council. Over its extended lifetime this project will collect and assemble a large volume of biologic and physical data for use by a wide range of stakeholders. The data system that is used by these stakeholders to access these disparate data will be critical to the successful delivery of these data and the overall benefit of the monitoring program. The issues relating to this data system are therefore closely linked to the goals of the long-term monitoring program and need to be included as the program is planned and designed. These issues include the impact of certain types of data and groups of users on the overall design and scope of the data delivery system.

Sources of data

Although the datasets and data sources are under evaluation the following general types of data have been under discussion since the special GEM session at the EVOS meeting in 1998:

- Physical oceanographic data collected at buoys, other stationary, towed, and floating instruments. Satellite based Synthetic Aperture Radar (SAR) may provide additional insight into the currents of Prince William Sound and the North Gulf of Alaska.
- Oceanographic biology data collected in bottle samples, stationary sensors, and perhaps remotely sensed ocean color images.
- Zooplankton data from net tows and possibly hydro acoustic sampling or enhanced optical counters

- Data on the growth and distribution of forage fish and other nekton species collected in net tows and by acoustic sampling.
- Data on apex predators, including sea birds and marine mammals.

The sources of these data are also of great importance to the operation of a data archiving system. Data policies, data format, lag time, and data ingestion may be quite different for different sources. A subset of the possible sources of data for GEM include the following:

- Previous EVOS funded projects and other focused research efforts. These efforts include the ecosystem projects as well as the more species-specific projects. Together the EVOS funded research will provide future researchers with baseline data that was unavailable in the spring of 1989.
- Repeated measurements needed for time series data that must be collected in a consistent manner over the lifetime of GEM.
- Targeted research to answer specific hypotheses about the ecosystem.
- Relevant Federal or State data including remotely sensed data and historical data
- Data from external research efforts that would like to utilize the archive facility.
- Results from models which describe or predict any of the relevant variables

The data system might manage two other critical types of data as well: GIS data, and text documents and reports. GIS data are maintained by several state and federal agencies and are an important component of most regional analysis. These data might be included in the archive or accessed from distributed archives through an interoperability layer. Many of the current scientific data systems are blending geographic data and measured data to provide context for science and enriched geographically oriented analysis.

Published and unpublished text documents are already available electronically in large volumes and this trend will continue. Making final reports available, along with the data, is often the best data documentation possible. Both GIS and text data can be extremely useful in finding relevant data. Data are often requested using specific geographic features, and if datasets are linked to electronic reports, full text search can be used to locate datasets of interest.

The data submission policies will also effect interaction between GEM and data suppliers. The policy for how and when data is supplied to the archive, needs to be part of the RFP process and these policies will effect the design and goals of the data system that will support the archive.

Users of Data

While, the types and sources of data effect the operation and structure of the data system, the selection of groups that the long-term monitoring program intends to support will effect the functionality of data system. This targeted user community is still being defined, but the current estimate includes:

- Earth system scientists who are analyzing the long-term trends in the region.

- Land use planners and managers who are granting permits and evaluating the impact of development.
- Applied scientists who support the local and state agencies with regional analysis.
- Local communities and fisherman who have a vested interest in the resources.
- Educators and students at the secondary or college level.
- Industrial stakeholders including Alyeska and the tourist industry.

The user base may or may not include any one of these groups but each one presents a unique set of challenges and requirements for the design of the data delivery system.

In summary, the impact of GEM in the long term will depend, in no small part, upon how it is viewed through its data system. A successful data system will depend on cataloging the critical issues associated with the data and the target user community and incorporating those into the planning process.

B. Rationale

Effective planning for the data system should begin with clarifying goals of the system and reviewing the prior work done in this area. As those goals are set, the significance of each needs to be understood and supported with background research. Planning the complete data system includes an analysis of the data supply and user demand, as well as the available technology that might be utilized, but our rationale is to start small. The planning can begin with small steps that will help clarify the goals and the ramifications of setting those goals. One of the first steps is to frame the initial issues and consider design and success of similar data delivery systems. The next step is to estimate the funding that might be available to develop and maintain a data system in order to constrain the design and form a reasonable set of expectations.

We are proposing to conduct this background research and combine it with our EVOS related data collection and archiving experience into a final report of data system issues. These include questions about the user community, the data types and sources and the long-term administration of the archive. Once this is completed we will make an estimate of funding and outline at lease one data system that can be used as a strawman as GEM is planned. If more than one direction seems possible, we will propose several systems with different funding requirements, which could be used as reference points during the planning process.

As an example of the data issues, data on specific species that has been collected or recorded by hand may have a rich structure but it may include many errors related to manual entry. These data require additional effort as they are added to the database even though the volume can be quite manageable. On the other hand, measured data from remote or in situ instruments can be quite voluminous with errors that tend to be more systematic in nature. These data may require additional meta-data and place special demands on disk capacity. In addition, similar data from different sources may be recorded with different levels of precision and may be submitted to the archive in different units and formats. The ability of the monitoring program to establish the desired formats will depend entirely on the data source. Monitoring efforts may be funded to produce data in a specific format but the researcher may define the format of the results from historic or ad hoc research.

The functionality of the system depends on the intended user community. Ecosystem and earth system scientists may want raw data along with complete documentation as to how, when, and where those data were collected. Resource managers on the other hand, are interested in some standard data products that can be used on a regular basis to evaluate he impact of ongoing management policies. Both groups may be interested in some level of on line analysis and GIS integration but the specifics are likely to be quite different.

The scientific community has developed a wide variety of data systems that address these problems to a lesser or greater degree. These include systems built by NASA, NOAA, USGS, and NSF to display and distribute a wide range of data. A short list includes:

- NASA distributes both earth and space science data on a large scale and has funded a number of interesting centralized and grass roots data systems including the Space Physics Data System and several system for the EOS project.
- NOAA maintains archives for fisheries and oceanographic data and has also funded several data systems. These include systems at the National Ocean Data Center and the Coastal Services Center.
- USGS has played an important role in National Spatial Data Infrastructure (NSDI) and the Federal Geographic Data Committee (FGDC). These standards are part of a growing network of spatial data providers.
- NSF has supported the Long-Term Ecosystem Research (LTER) program as well as funding and initiative devoted to the issues of digital libraries. GEM could be quite similar to these LTER sites
- The GLOBEC program also stores data similar to GEM and could possibly be a host GEM data, eliminating the need for a GEM data system

Unlike many of the federal data systems, however, the data system for GEM might be distributed in nature. Both scientific and GIS data for the northern Gulf of Alaska are maintained in many different federal, state, and local archives. This suggests that a successful data system could provide pointers to relevant data in similar archives and not replicate data. However, on a long-term scale our current data will become historic data and some of the distributed data may need to be saved in order to provide proper context and the EVOS data archive might be the only place that can provide a safe data haven.

C. Location

Since this is a data system related project it is not tied to any particular region of the northern Gulf of Alaska. The work will be conducted at the DC offices of ECOlogic Corp. and at the EVOS meeting or ad hoc meetings in Anchorage.

Project Design

A. Objectives

We will produce a report containing the results of our investigation that includes our combined experience in building and evaluating scientific and spatial data systems for the northern Gulf of Alaska. We will be estimating which data or users the long-term monitoring program will include and presenting the data system issues that will accompany those choices. Our report will include but may not be limited to the following topics:

- **Data types and Sources and the related issues.** The data issues include data complexity and volume, policies for collection and submission, ingestion requirements, other sites with similar data, and data formats and interoperability.
- **Possible user groups and requirements.** User requirements can vary greatly and we will present some of the needs of specific user groups. These include datasets and regions of interest, data download, and processing requirements during data delivery. One of the prime user issues will be the extent of online analysis and visualization that could be possible in GEM.
- **Other state and federal data archives.** We will review several existing archives and data systems and the ways in which these systems dealt with the challenges we have outlined.
- **Other Alaskan and EVOS related archives.** We will look at some of the existing databases created for EVOS projects such as SEA, NVP, and Apex. Although a comprehensive inventory of existing data is beyond the scope of this effort, we will follow the suggestions of the advisory committee and estimate the data available from recommended EVOS funded projects.

Secondary topics will include:

- **Potential functionality of data system.** The functionality can range from simple download of raw data to comprehensive query, visualization and analysis. We will discuss this range and use the existing data system examples and some of the tradeoffs between specific functionality and general accessibility.
- **Long-term archive administration.** The long-term administration will include the operational facilities and personnel that will be required to maintain the system over its lifetime.
- **Software and hardware questions.** We will present some of the software and hardware issues including existing commercial software that may be available for particular types of data (e.g. GIS data)

B. Methods

The methodology will include the following general steps:

- Assist in the establishment of a data system advisory committee and create an operations plan to be reviewed by that committee. This will be an important step in establishing a standing advisory committee for the GEM data and information system.

- Collect the most recent description of GEM and estimate the data types and sources that could be involved. This will also provide insight into the likely or intended user community.
- Review several existing data systems and establish a taxonomy in which they can be classified and discuss the technical requirements for the different types of systems.
- Contact the data managers for some of the key EVOS projects and gauge the effort needed to incorporate existing EVOS project databases into the GEM system
- Propose one or more data system "strawmen" at different funding levels that provide a range of options for the planning committee.

Establishing an advisory committee

In the long term, a standing advisory committee should be responsible for setting the goals and policies for the GEM data system. This committee will provide an independent validation of the ongoing data system development and help make the critical decisions about target user community and the scope of the system. Although any funding might be needed to support this advisory committee is not included in the budget of this proposal, there is time allocated to assist the Director in building this committee and for regular meetings with them.

Data and user estimates

Drawing on the current vision of GEM and our experience with other EVOS and non-EVOS data systems, we will outline the data types and sources that can be anticipated by GEM. This outline will be accompanied by a description of the common data system issues that are associated the data anticipated data. In addition, we will describe the user groups and the framework in which they would best be able to utilize the data from the long-term monitoring and research program.

Data system review

Although there are great many scientific data system currently available on the web, our goal will be to quickly identify exceptional examples that illustrate the overall taxonomy of these systems. We will first look at the Long Term Ecological Research (LTER) archives that are funded by the National Science Foundation. This project is committed to long-term research and archiving and may provide a valuable reference point for the GEM long-term archive.

NASA and NOAA have also implemented several scientific data archives that will be useful. The NASA EOS program is focused on the problems of a large volume of remote sensing data but it may still have some relevance. In addition, NASA has overseen the development of several grass roots data systems including the Space Physics Data System (SPDS) and the Planetary Data System (PDS). These may both provide interesting examples of successful data systems, built by and for scientists. NOAA also has several data archives including the National Oceanographic Data Center (NODC) and fisheries archives for the National Marine Fisheries Service (NMFS). These may provide good examples of relevant scientific archives as well as potential sources of data. They may also be possible host sites if GEM chooses to use an existing system.

Other possible project data archives include the GLOBEC and FOCI projects. Although the data systems for these projects may not be available to the public, these efforts are similar in mission to GEM and deserve special attention as examples from which GEM can draw. They may also be possible host sites for a shared regional archive.

An effort spawned by NSF has been researching the requirements of digital libraries and this could be of great interest to the GEM planning group. The Alexandria Digital library focuses on spatial data in digital form and will be a useful example. As this aspect of the project unfolds, several other potential scientific archives may emerge and could be included in the investigation.

We will also examine the current state and use of the existing databases that maintain data on the northern Gulf of Alaska. Some of these will be EVOS funded projects including SEA, Apex and the hydrocarbon database. In addition, we will include the CIIMMS system from the Alaska Department of Natural Resources in our data system taxonomy.

Many of the regional archives include GIS data and text. We will examine how these data type in specific are being managed and how they might be incorporated into the data system for GEM. Some of this perspective will come from systems that manage other large scientific archives in conjunction with GIS data.

Existing EVOS databases

One key data source will be the existing EVOS databases. Of particular interest are the ecosystem projects, SEA, Apex and NVP. However there are many potential data sources from the array of EVOS funded projects. Although a complete catalog of possible datasets is beyond the scope of this proposal, we will contact data managers for the recommended projects and document the types of data and scope of the effort that will be needed to incorporate these existing datasets into the GEM system. We have allocated several weeks for this process.

Strawman proposals

Ideally we would like to propose multiple strawman system that might be quite different. These could include partnering with an existing data system such as NODC or GLOBEC, building a minimalist system that delivers only raw data files, or building a more complete system that includes analysis and visualization. Another choice might be to reuse an existing system such as Alexandria digital library or the Mercury system developed by the Oak Ridge National Laboratory and place it under a GEM banner. These choices will require different levels of funding and will fall within of the data system taxonomy developed during the data system review. The hardware and software options and the personnel and management ramifications will be included as well.

Report preparation

The final report will include all of the above results including the strawman proposals. In addition a simple web page will be included with pointers to the relevant sites with annotations describing the taxonomy and how each system is classified. Several weeks have been allocated for this as well.

C. Cooperating Agencies and Groups

The project will be led by Charles Falkenberg from ECOlogic Corp. and include collaborators from the Advanced Visualization Lab at the University of Maryland and the Alaska Department of Natural Resources. The individuals from these groups bring a unique perspective to this project and their responsibilities are described in the section entitled "key personnel" and included in the attached letters of support.

The Chief Scientist and the office of the Executive Director will provide general direction for the project as well. This will include the goal of forming of an advisory panel who would be tasked with the responsibility of reviewing user needs, evaluating the potential data sources, and providing some insight to the target systems.

Schedule

A. Measurable tasks for FY00 (Oct 1 1999 – Sept 30, 2000)

December 31:	Complete plan for background research and a working list of possible advisory committee members.
January 18 or 28:	Attend EVOS annual meeting. Meet with the advisory committee and with other interested parties.
July 30:	Complete final report of data system issues and background.

B. Project milestones

We expect our effort will require about 5 person months of research, analysis and report writing. In that time we will be reviewing the existing systems, contacting individuals who can provide insight into particular data systems, and writing up the report. The report will be intended for the planners of the long-term monitoring and research program with the hope of adding insight to the planning process.

The research and analysis will be conducted on either side of the annual EVOS meeting in January 2000. The initial work will be done before the meeting and we will use that meeting as an opportunity for the collaborators to evaluate the research and outline the report. Any additional research will be done after the Symposium and final report will be produced by the end of July.

Reports

The final report for this project will include the results of our background research and the issues related to the data system for the long-term monitoring program.

Principal Investigator

Charles Falkenberg
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Washington, DC 20001
Phone: 202-218-4100
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Email: csfalk@ecologic.net

Charles Falkenberg has an MS in computer science and has been involved in building database systems since 1980. He was the principal developer of the archive and data system for the EVOS Sound Ecosystem Assessment (SEA) project. He has 20 years experience designing and building database systems and has worked for the last 6 years on several different scientific data systems. These included data management systems for hydrologic data, oceanographic data, NASA's Earth Observing System (EOS) data, and data environmental assessment at a local and national level. ECOlogic Corp. is a software development and consulting firm, specializing in spatial data management for science and industry. It is currently working on three NASA projects developing tools and applications for EOS data archiving and analysis.

Other Key Personnel

Ravi Kulkarni developed the CDF scientific data format and has been involved with both space science data systems and visualization. He is currently working on a NASA project that is exploring techniques for standardizing the process of data publication. He will evaluate several of NASA grass roots data systems and provide an analysis of potential data publishing techniques. In addition, he will assist in developing the data system taxonomy and in the preparation of the final report

Carol Fries is a Natural Resource Manager in the Office of Commissioner, EVOS at the Alaska Department of Natural Resources and has been involved in organizing the EVOS CD and GIS data for the EVOS region. ADNR is currently implementing the Cook Inlet Information Management and Monitoring System. This system is still in the formative stages but could be a clearinghouse of clearinghouses providing a central location for national and regional data related to Cook Inlet and the watersheds that feed it. The CIIMMS project is headed up by Kelly Zeiner who, along with Carol, will provide insight into CIIMMS and a perspective on the GIS data that need to be accessed as well as wide variety of data that been collected as part of ongoing EVOS research.

Vince Patrick is a founding member of the SEA project and is the principal investigator for the SEA modeling effort as well as the SEA database. He has been involved with the data issues in SEA and brings a deep understanding of the challenges of ecosystem analysis. Although not directly involved with this project Vince will be available to review the report and comment on the demands that ecosystem modelers place on a scientific data management system.

Revision 30-99
Approved TC 8-9-99

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

Budget Category:	Authorized FY 1999	Proposed FY 2000						
Personnel		$0.0						
Travel		$0.0						
Contractual		$83.2						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$83.2			Estimated FY 2001	Estimated FY 2002		
General Administration		$5.8						
Project Total	$0.0	$89.0						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Project Number: 00455-BAA
Project Title: Evaluation of Data System for EVOS Long-Term Monitoring Program
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Revision 7-30-99

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:		Authorized FY 1999	Proposed FY 2000			Estimated FY 2001	Estimated FY 2002		
Personnel			$66.5						
Travel			$2.8						
Contractual			$0.0						
Commodities			$0.0						
Equipment			$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal		$0.0	$69.3						
Indirect	20%		$13.9						
Project Total		$0.0	$83.2						
Full-time Equivalents (FTE)			0.6						
		Dollar amounts are shown in thousands of dollars.							
Other Resources									

Comments:
Direct cost include salary and benifits
Indirect costs include General and Adminstrative expenses

FY00

Prepared: 1-Jul-99

Project Number:
Project Title: An Evaluation of the Data System for the EVOS Long Term Monitoring Program
Name: Charles Falkenberg

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
Charles Falkenberg	Principal Investigator		6.0	9.5		57.0
Ravi Kulkarni	Co-Investigator		1.0	9.5		9.5
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		7.0	19.0	0.0	
					Personnel Total	$66.5

Travel Costs:		Ticket	Round	Total	Daily	Proposed
Description		Price	Trips	Days	Per Diem	FY 2000
EVOS Annual Meeting	Plane fare and hotel charges	1.0	1	5	0.1	1.5
Project status trip	Plane fare and hotel charges	1.0	1	3	0.1	1.3
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$2.8

FY00

Project Number:
Project Title: An Evaluation of the Data System for the EVOS Long Term Monitoring Program
Name: Charles Falkenberg

FORM 4B
Personnel
& Travel
DETAIL

Prepared: 1-Jul-99

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Contractual Costs:	Proposed
Description	FY 2000
Contractual Total	$0.0

Commodities Costs:	Proposed
Description	FY 2000
Commodities Total	$0.0

FY00

Prepared: 1-Jul-99

Project Number:
Project Title: An Evaluation of the Data System for the EVOS Long Term Monitoring Program
Name: Charles Falkenberg

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
			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 Title: An Evaluation of the Data System for the EVOS Long Term Monitoring Program
Name:

FORM 4B
Equipment
DETAIL

Prepared: 1-Jul-99

approved TC 8-9-9

Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska

Project Number:	00459-CLO
Restoration Category:	Monitoring
Proposer:	G. Irvine/USGS-BRD
Lead Trustee Agency:	DOI
Cooperating Agencies:	NOAA
Alaska SeaLife Center:	No
New or Continued:	Cont'd
Duration:	2nd yr. 2 yr. project
Cost FY 00:	$40.0
Cost FY 01:	$0.0
Cost FY 02:	$0.0
Geographic Area:	Alaska Peninsula, Kenai Peninsula
Injured Resource/Service:	Designated wilderness areas, mussels, interidal communities

ABSTRACT

During FY 00, this project will focus on data and hydrocarbon analyses, preparation of the final report, and preparation and submittal of two manuscripts. Funding is requested for presentation of study results at a professional meeting. In FY 99, boulder-armored beach sites and several oiled mussel beds in the Gulf of Alaska are being resampled to determine whether oil persists.

INTRODUCTION

This proposal is focused on shoreline oiling in the Gulf of Alaska, the continued presence of subsurface oiling, and the situations that promote oil persistence and retard weathering of stranded oil. The continued contamination of shorelines and biotic communities by residual *Exxon Valdez* oil, especially slowly weathering oil, is a concern of direct relevance to the recovery status of injured resources and services. The *Exxon Valdez* oil spill directly affected the scientific and recreational values including wilderness characteristics of shorelines in Kenai Fjords National Park and Katmai National Park and Preserve. The injury to these values and characteristics is continued by the persistence of oil that degrades the "naturalness" of the coasts. These values and characteristics are clearly stated in both ANILCA (1980) and the Wilderness Act (1964). Additionally, the retention of oil by mussel beds in the Gulf of Alaska and its retarded weathering is of some concern, as the mussel beds are reservoirs of oil that could be released into the environment or contaminate foragers of the mussels.

The exposed Gulf of Alaska habitats where oil has persisted and mussel beds share some common features. They have complicated three-dimensional spatial structures, which allow stranding oil to penetrate into more protected sediments beneath an "armor" of boulders or mussels. Oil thus sequestered is slower to weather (Babcock et al. 1994, 1996, 1998; Irvine and Cusick 1995; Irvine et al. 1997, 1999; Short and Heinz 1997). In fact, oil sampled five years post-spill at sites along national park coasts distant from the spill point was negligibly different from 11-day old *Exxon Valdez* oil (Irvine et al. 1997, 1999). The oil contaminating these coasts was mousse, a water-in-oil emulsion that weathers more slowly internally (Payne and Phillips 1985) and can serve to transport less weathered oil over long distances (Irvine et al. 1997, 1999).

In general, the shorelines impacted by *Exxon Valdez* oil in the Gulf of Alaska region experience higher wave energy than those inside Prince William Sound (Hayes et al. 1977; Hayes and Ruby, 1979; Domeracki et al. 1981; Hayes 1986). Gravel beaches, those composed of mixtures of sand, pebbles, cobbles and boulders, are the most common type of non-bedrock shorelines in the Gulf of Alaska region (Hayes et al. 1976). Gravel beaches exposed to moderate and high wave energies characteristically develop a lag of boulders (stones > 25 cm in diameter) after smaller stones are winnowed away by waves. This boulder lag forms an "armor" that shields the gravel substrate from wave disturbance. Unaffected by all but the largest storm waves, the gravel substrate under a boulder armor can remain undisturbed for years. Observations in the study plots we have established to monitor the persistence of surface oil in Kenai Fjords and Katmai National Parks suggest that on 5 of 6 boulder-armored beaches, no shifting of the boulder armor occurred for 6 years post-spill (Mann et al. 1995).

The length of time that spilled oil remains on a shoreline is thought to depend on the vigor of wave action (Vandermuelen 1977; Gundlach 1983). Frequent large waves breaking on a beach cause vigorous natural cleaning and consequently a short residence time for stranded oil. However, the *Exxon Valdez* spill affected numerous gravel beaches, many possessing the boulder armoring just described. While high wave energy does seem to limit the persistence of surficial oil on gravel beaches, it may have little effect on the persistence of subsurface oil. Subsurface oil can persist even within high wave-energy gravel beaches because the boulder armor prevents waves from stirring the beach substrate.

Results of our several-year study of oil fate and persistence on beaches in Kenai Fjords and Katmai National Parks indicate sizable reductions in the amount of surficial oiling there. However, observations made in 1994 indicate that significant amounts of subsurface oil remain within gravel beaches along the Katmai coast of Shelikof Strait, even after these beaches were cleaned at the surface. Similar inferences emerge from the studies of Michel and Hayes (1993a, 1993b, 1994, 1996) and Neff et al. (1995) on the fate of shore-stranded oil on Prince William Sound shorelines. This study is a continuation of our monitoring of persistent oil in the Gulf of Alaska region on previously established sites along national park coastlines. Additionally, we will be resampling oiled mussel beds along the Kenai Peninsula.

Study History:
Both the stranded oil persistence study and the oiled mussel bed study were previously funded by the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC). The oil persistence study (R103B, 93090, 94266) was funded for field work in 1992, 1994, and 1999. Six moderately to heavily oiled sites along the Gulf of Alaska coasts of Kenai Fjords National Park and Katmai National Park and Preserve will have been studied for both surficial and subsurface oiling changes, and oil samples analyzed to examine the degree of weathering of the oil. Although five of these sites are very high energy beaches, sampling in 1992 and 1994 indicated that oil mousse persisted in a remarkably unweathered state on these boulder-armored beaches. Mousse sampled in 1989, 1992, and 1994 showed negligible changes in polynuclear aromatic hydrocarbons compared to 11-day old *Exxon Valdez* crude (Irvine et al. 1997, 1999). Our earlier findings also suggest that the low ecological sensitivity ratings previously applied to exposed, rocky shorelines need to be modified when boulder-armored beaches are present.

The study of oiled mussel beds in the Gulf of Alaska (R103B, 93090, 95090), was a companion to studies of oiled mussel beds in Prince William Sound being spearheaded by NOAA. The objectives of the previous study were to establish the geographical extent and intensity of the oiling of mussel beds, and to determine the rate of recovery of those beds that were oiled. In 1999 we will be resampling the 3 sites sampled in 1995 that had the highest levels of oiling.

NEED FOR THE PROJECT

A. Statement of Problem

Oil from the wrecked T/V *Exxon Valdez* spread from Prince William Sound out into the Gulf of Alaska, stranding on coastlines of the Kenai and Alaska Peninsulas and the Kodiak Archipelago. As recently as 1993 and 1994, oil remained in particular types of locations in the Gulf of Alaska. These included boulder-armored intertidal beaches and mussel beds. As stated on page 19 of the

Invitation to Submit Restoration Proposals, "The oil that remains in the environment and the extent and significance of any biological exposure to that oil continues to be an important concern of direct relevance to the recovery status of injured resources and services."

The persistence of oil on national park coastlines (sites are located on Kenai Fjords and Katmai National Parks) constitutes injury to the scientific, recreational, and wilderness values of the parks. While we assess the significance of the oiling, we will also be assessing the recovery of oiled sediments through natural processes of physical and chemical weathering of the oil.

The three-dimensional topography of mussel beds creates a situation similar to that of boulder-armored beaches, where oil has penetrated finer sediments beneath the mussels but is protected to some extent from disturbance and weathering processes. The same questions regarding the retention and weathering can be asked for mussel beds as for the boulder-armored beaches. Additionally, since predators feed on the mussels, there is the potential for exposure of the predators to hydrocarbons. In the Nearshore Vertebrate Predator project in PWS, invertebrate-feeding predators (sea otters and Barrow's goldeneye ducks) have shown elevated levels of biomarkers that may indicate increased exposure of the animals to hydrocarbons, though the linkages to sources and the significance of the results are not known. Results from various projects presented at the recent 10th year anniversary Restoration Conference reinforce this view, and elevate the concerns regarding residual oiling as a source of continuing contamination.

B. Rationale/Link to Restoration

This project has a very basic link to oil spill effects: we are studying the persistence and degradation of stranded oil. The project is primarily a monitoring project. The monitoring elements are straightforward reassessments of the persistence and degradation of oil on boulder-armored beach sites and in oiled mussel beds. In 1999, we will be monitoring surface-oil weathering at six sites already established in the Gulf of Alaska, as well as subsurface oiling. Both physical and chemical weathering of the oil will be assessed. Also in 1999, we'll be resampling oiled mussel beds at three locations using previously established techniques to determine the chemical weathering of hydrocarbons in both mussel tissue and sediments underlying the mussels. The results obtained will help describe the progress of recovery of oiled sediments and biota. Results will guide decisions about whether future restoration efforts are desirable and how they might be implemented.

Our results will also help predict the effects of future oil spills in this region and guide future oil-spill response efforts. In particular, our results suggest that a revision to the Ecological Sensitivity Indices (ESI's) for boulder-armored exposed rocky shores may be necessary, and that instead of being rapidly cleansed by wave action, these sites are locations where oil may persist for decades with minimal weathering. This revision could lead to changes in response and cleanup strategies for these habitats.

C. Location

Sites that are being resampled are located in the Gulf of Alaska along Kenai Fjords and Katmai National Park coasts, and the outer Kenai Peninsula.

COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

At present, there are no communities in the vicinity of the study areas. We will be happy to present information to the nearest local communities and/or prepare lay abstracts of our work.

PROJECT DESIGN

A. Objectives

1999:

1. Monitor (a) surface and (b) subsurface oil at 6 previously established sites along the Gulf of Alaska coast. Determine the physical extent and chemical weathering of the oil.

2. Monitor recovery of a select subset (3) of previously sampled Gulf of Alaska oiled mussel beds.

2000:

3. Preparation of Final Report and submission of two manuscripts to peer-reviewed journals.

4. Presentation at a professional conference.

B. Methods

Sampling methods at the boulder-armored beaches will include: relocation and resampling of permanently marked quadrats, gas chromatography/mass spectroscopy (GC/MS) analysis of oiled sediment samples from each site, and analysis of sub-surface oiling by sampling "dip stones". At the oiled mussel sites, 3 pooled samples each of mussels and sediments will be taken relative to a transect laid along the zone of heaviest oiling of the mussel bed.

The following section details the hypotheses and methods associated with each of the Objectives listed above.

1. a. *Monitor surface oil at 6 previously established sites.*
Continued monitoring of the fate of stranded surface oil on Gulf of Alaska shorelines indicates gradual disappearance of this oil. We hypothesize that surficial oil will have disappeared entirely by 1999 (5 years since the last sampling and 10 years post-spill).

   Methods established in 1994 will be used to reassess the surficial oiling at the 6 sites previously established along the coasts of Kenai Fjords and Katmai National Parks. Oil percent cover will be estimated visually in the field within 10-25 quadrats per site previously set up and marked by rock bolts. Independent estimates by observers will be compared and estimates modified until all observers agree on oil coverage within 5% (Dethier et al. 1993).

1\. b. *Monitor <u>subsurface</u> oil at the 6 previously established Gulf of Alaska sites.*
We hypothesize that oil trapped in the subsurface of boulder-armored gravel beaches will remain there for lengthy intervals and will weather slowly since it is shielded from both physical abrasion and evaporation. We will monitor the persistence and chemical weathering of the buried oil by systematically examining "dip stones" within the oiled area and by analyzing 2 samples of oiled sediments taken at each site via GC/MS. Both of these methods were used in 1994. The extent of subsurface oiling will be assessed via dip stones, which are elongate rocks protruding out of the surface but extending down into the subsurface oil layer. The ideal dip stone extends vertically below the lowest subsurface oil, illustrating the maximum depth of oiling at that spot. GC/MS analyses of oil samples will provide an indication of oil weathering in addition to identifying the oil as *Exxon Valdez* oil. The Auke Bay Laboratory has offered to conduct, gratis, GC/MS analyses of 6 oil samples from these sites. We will analyze an additional 6 samples in order to replicate our previous sampling effort.

2\. *Monitor recovery of 3 Gulf of Alaska mussel beds previously sampled in 1993.*
Previous sampling of oiled mussel beds along the Gulf of Alaska coast suggested that levels of hydrocarbons in mussels and in the sediments underlying the mussels were declining (Irvine and Cusick 1995; Babcock et al. 1996, 1998). However, several mussel beds sampled in 1995 had levels of hydrocarbons above baseline levels (50 μg/g total petroleum hydrocarbons [TPH] wet weight in sediments and 0.09 μg/g total polynuclear aromatic hydrocarbons [TPAH] dry weight in mussels). These baseline levels are determined from the minimum detection limits of the analytical instruments and historical data from unoiled sites in Prince William Sound. We will examine three beds on the outer Kenai Peninsula (Tonsina Bay, Port Dick and Morning Cove) in order to assess the recovery of these assemblages. We predict that levels should have declined further, perhaps to background levels. We will use the same methods as in previous years, and will take 3 pooled samples each of mussels and underlying sediments. Samples will be analyzed by GC/MS at the Auke Bay Fisheries Laboratory. NOAA will be resampling beds in PWS, and combination of PWS and GOA sampling should provide a broad picture of the recovery status of these oiled beds.

Statistical Analyses

<u>Shoreline Oil Persistence and Weathering</u>:
Surficial Oil: Surface oiling is reassessed in marked quadrats by estimates of oil percent cover. Percent cover data for individual quadrats will be compared through time (1994 and 1999 data) via pair-wise tests. As for all tests discussed, the data will be tested for normality and the

appropriate parametric or non-parametric test chosen. The power to detect change is usually increased when fixed quadrats are used as a sampling method, although the resulting inference is limited to changes within that particular quadrat. Since we have only one year of data, we cannot project the anticipated variability within quadrats over time.

Subsurface Oiling: Subsurface oiling will be assessed through sampling of dip stones at each site. Means and ranges of the depth of oiling for each site will be compared through time.

Oil Weathering: The presence and relative abundance of polynuclear aromatic hydrocarbons (PAH) within samples will be compared, and a weathering index based on a first-order kinetic loss rate model of Short and Heinz (1997) will be used to compare the degree of weathering of different samples at the same and different sites.

Oiled Mussels:
The parameters described above to be used in comparing the oiled sediment samples (relative abundances of PAHs and an EVO weathering index) will be used to compare the oil in samples of mussel tissue and underlying sediment. The change in the percent phenanthrenes of samples in samples analyzed by GC/MS will also be compared (Babcock et al. in prep). Additionally, uv-fluorescence (Krahn et al. 1991) will be used initially to analyze sediments associated with the mussel beds. Data from individual sites will be compared through time using paired tests. The data from these outer Kenai Peninsula sites will also be compared to data from PWS. Power analyses from another mussel hydrocarbon monitoring study (Kinnetics 1993) suggests that triplicate sampling such as we propose could have the statistical power of 80% to detect a change or difference of 60% (alpha = 0.05) at two sites or two sampling times at the same station.

C. Cooperating Agencies, Contracts, and Other Agency Assistance

NOAA is a cooperating agency, as one of our Principal Investigators, Dr. Jeff Short, is allied with the NOAA's Auke Bay Fisheries Laboratory. We also expect to cooperate with the NOAA's Principal Investigators on the PWS Oiled Mussel project, although we are submitting separate proposals.

SCHEDULE

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

January 15:	Complete data analysis and hydrocarbon analyses from 1999 field season
January 18-28:	Attend Annual Restoration Workshop
April 15:	Submit Draft Final Report (FY99 findings)
September 30:	Submit manuscripts to peer-reviewed journals

B. Project Milestones and Endpoints

Objective 1: *Monitor surface and subsurface oil at 6 previously established sites along the Gulf of Alaska coast. Determine the physical extent and chemical weathering of the oil.*
Field monitoring should be completed during summer 1999. Analysis of data will occur in the fall, and results of the hydrocarbon analyses are expected in Jan. 2000.

Objective 2: *Monitor recovery of 3 Gulf of Alaska mussel beds previously sampled in 1993.*
The mussel beds will be sampled during the summer of 1999. Results of the hydrocarbon analyses are expected in Jan. 2000.

Objective 3: *Preparation of Final Report and submission of two manuscripts to peer-reviewed journals.*
As stated in greater detail above, the field work for the project is expected to be completed in FY99, with data analysis the following fall, hydrocarbon analyses in the fall and winter, and a draft final report submitted in April 2000. We expect to submit two manuscripts in FY 2000 (one in conjunction with NOAA's oiled mussel project).

Objective 4: *Presentation to a professional conference.*
We plan to present the findings of our research at a professional conference in FY2000.

C. Completion Date

We initially planned on completing all aspects of this project by the end of FY 2000, however, we now anticipate preparation and submittal of an additional manuscript and a presentation at a conference in FY 2001.

PUBLICATIONS AND REPORTS

We have a paper covering our previous geomorphology-oiling results in press at Marine Pollution Bulletin, and another manuscript on spill-wide recovery of oiled mussels (lead by NOAA), due to be submitted shortly. In FY 2000, we plan to submit another paper encompassing our 1999 results on oil persistence and degradation at high-energy armored beaches. We want to examine the results before before deciding which journal to submit to. We will participate in preparation of an additional oiled mussel manuscript that looks at the spill-wide recovery of oiled mussel beds. In FY 2001, we plan to prepare an additional manuscript on oiled mussels ("Spatial variability in oiling within mussel beds distant from the Exxon Valdez spill origin"). This work will also be presented at a scientific meeting.

We will prepare a Draft Final Report by April 15, 2000 and Final Report in FY 2000.

PROFESSIONAL CONFERENCES

Results from this project will be presented at a conference in FY2000, with another presentation planned for FY2001.

NORMAL AGENCY MANAGEMENT

This project is not at all part of any normal agency management. It is being proposed solely because the *Exxon Valdez* oil spill occurred and contaminated coastlines and biota.

COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project is built on the framework of two previously funded EVOSTC projects that the Prinicpal Investigators have been involved with. One of our PI's is with NOAA's Auke Bay Laboratory, and we expect to coordinate data analysis and results from the oiled mussel samples with the NOAA PI's examining oiled mussels in Prince William Sound.

PRINCIPAL INVESTIGATORS

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Revis 7-8-99
approved TC 8-9-99

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Budget Category:	Authorized FY 1999	Proposed FY 2000	PROPOSED FY 2000 TRUSTEE AGENCIES TOTALS					
			ADEC	ADF&G	ADNR	USFS	DOI	NOAA
							$35.4	$5.4
Personnel	$0.0	$18.5						
Travel	$0.0	$2.2						
Contractual	$0.0	$15.3						
Commodities	$0.0	$0.1						
Equipment	$0.0	$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$36.1			Estimated FY 2001	Estimated FY 2002		
General Administration	$0.0	$3.9						
Project Total	$0.0	$40.0			$20.0	$0.0		
Full-time Equivalents (FTE)	0.0	0.2						
	Dollar amounts are shown in thousands of dollars.							
Other Resources	$0.0	$0.0			$0.0	$0.0		

Comments:

Cooperative Agreement with University of Alaska, Fairbanks. Indirect Costs 15%, USGS-UAF agreement
Manuscript preparation: Total of 1.5 mo of personnel time (Irvine-0.75 mo; Mann- 0.5 mo; Short-0.25 mo)

FY00

Prepared: 4/99

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Lead Agency: DOI-BRD

FORM 2A
MULTI-TRUSTEE
AGENCY SUMMARY

	Authorized	Proposed

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

Budget Category:	FY 1999	FY 2000						
Personnel		$14.8						
Travel		$2.2						
Contractual		$15.3						
Commodities		$0.1						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$32.4			Estimated FY 2001	Estimated FY 2002		
General Administration		$3.3						
Project Total	$0.0	$35.7			$20.0			
Full-time Equivalents (FTE)		0.2						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Prepared: 4/99

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: DOI-BRD

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 2000

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

Dr. Gail Irvine	Marine Ecologist	GS-12	2.0	7.4		14.8
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		2.0	7.4	0.0	
					Personnel Total	$14.8

Travel Costs: Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Proposed FY 2000
Anchorage-Salt Lake City	1.0	1	6	0.2	2.2
(Present findings at Ecological Society of America Mtgs)					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$2.2

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: DOI-BRD

FORM 3B
Personnel
& Travel
DETAIL

Contractual Costs: Description	Proposed FY 2000
Cooperative Agreement with University of Alaska	13.7

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

Final report production	1.0
Registration for scientific meetings	0.3
Duplication	0.3
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$15.3

Commodities Costs:	Proposed
Description	FY 2000
Film	0.1
Commodities Total	$0.1

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: DOI-BRD

FORM 3B
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
				0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.			**New Equipment Total**	$0.0

Existing Equipment Usage:	Number	Inventory
Description	of Units	Agency

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: DOI-BRD

FORM 3B
Equipment
DETAIL

Budget Category:	Authorized FY 1999	Proposed FY 2000
Personnel		$3.7
Travel		$0.0

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Contractual		$0.0						
Commodities		$0.0						
Equipment		$0.0	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$3.7			Estimated FY 2001	Estimated FY 2002		
General Administration		$0.6						
Project Total	$0.0	$4.3						
Full-time Equivalents (FTE)		0.0						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

Personnel Costs:		GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Proposed FY 2000
Name	Position Description					
Dr. Jeff Short	Hydrocarbon Chemist	GS-13	0.4	9.3		3.7
						0.0
						0.0
						0.0

						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		0.4	9.3	0.0	
					Personnel Total	$3.7

Travel Costs: Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	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
				Travel Total	$0.0

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

Contractual Costs: Description	Proposed FY 2000

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

When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$0.0

Commodities Costs:	Proposed
Description	FY 2000
Commodities Total	$0.0

FY00	Project Number: 00459 Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska Agency: NOAA	FORM 3B Contractual & Commodities DETAIL

Prepared:

New Equipment Purchases:	Number	Unit	Proposed
Description	of Units	Price	FY 2000
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0

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

				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
				0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.			**New Equipment Total**	$0.0

Existing Equipment Usage:	Number	Inventory
Description	of Units	Agency

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: NOAA

FORM 3B
Equipment
DETAIL

Budget Category:	Authorized FY 1999	Proposed FY 2000
Personnel		$9.0
Travel		$1.6
Contractual		$1.2
Commodities		$0.1
Equipment		$0.0
Subtotal	$0.0	$11.9

LONG RANGE FUNDING REQUIREMENTS

		Estimated	Estimated		

2000 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 1999 - September 30, 2000

Indirect		$1.8			FY 2001	FY 2002		
Project Total	$0.0	$13.7						
Full-time Equivalents (FTE)		0.1						
	Dollar amounts are shown in thousands of dollars.							
Other Resources								

Comments:

See attached form 4B's for detail

UAF: University of Alaska, Fairbanks, Cooperative Agreement ; 15% indirect costs (UAF-USGS rate)

Travel includes travel to the Annual Restoration Workshop, plus an additional trip to work on manuscript

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: University of Alaska, Fairbanks (UAF)/ Agency:DOI-BRD

FORM 4A
Non-Trustee
SUMMARY

Personnel Costs:							
	Name	Position Description		Months Budgeted	Monthly Costs	Overtime	Proposed FY 2000
	Dr. Dan Mann	Geomorphologist		1.5	6.0		9.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0
							0.0

						0.0
						0.0
						0.0
						0.0
	Subtotal		1.5	6.0	0.0	
					Personnel Total	$9.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 2000
	Fairbanks-Anchorage, RT	0.3	2	5	0.2	1.6
	(includes travel to EVOS Annual Restoration Workshop)					0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
					Travel Total	$1.6

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: DOI-BRD

FORM 4B
Personnel
& Travel
DETAIL

Contractual Costs:	Proposed
Description	FY 2000
Page charges	1.0
Duplication	0.2

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

Contractual Total	$1.2

Commodities Costs:	Proposed
Description	FY 2000
Film	0.1
Commodities Total	$0.1

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: University of Alaska, Fairbanks (UAF)/ Agency: DOI-BRD

FORM 4B
Contractual &
Commodities
DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2000
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0

				0.0
				0.0
				0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.			**New Equipment Total**	$0.0

Existing Equipment Usage:	Number	
Description	of Units	

FY00

Prepared:

Project Number: 00459
Project Title: Residual Oiling of Armored Beaches and Mussel Beds in the Gulf of Alaska
Agency: University of Alaska, Fairbanks (UAF)/ Agency: DOI-BRD

FORM 4B
Equipment
DETAIL